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Economic Research Report Number 152

August 2013

Farm Size and the Organization of U.S. Crop Farming

James M. MacDonald, Penni Korb, and Robert A. Hoppe

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Abstract

Cropland has been shifting to larger farms. The shifts have been large, centered on a doubling of farm size over 20-25 years, and they have been ubiquitous across States and commodities. But the shifts have also been complex, with land and production shifting primarily from mid-size commercial farming operations to larger farms, while the count of very small farms increases. Larger crop farms still realize better financial returns, on average, and they are able to make more intensive use of their labor and capital resources, indicating that the trends are likely to continue. The report relies on comprehensive farm-level data to detail changes in farm size and other attributes of farm structure, and to evaluate the key driving forces, including technologies, farm organization and business relationships, land attributes, and government policies.

Keywords: cropland consolidation, crop production, large crop farm, farm size, farm size measure, farm structure, farm organization, family farm, industrial agriculture, farm finances

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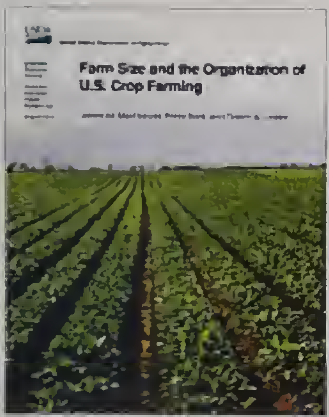

Find the full report at *www.ers.usda.gov/publications/err-economic-research-report/err-152.aspx*

Farm Size and the Organization of U.S. Crop Farming

James M. MacDonald, Penni Korb, and Robert A. Hoppe

What Is the Issue?

Large farms now dominate crop production in the United States. Although most cropland was operated by farms with less than 600 crop acres in the early 1980s, today most cropland is on farms with at least 1,100 acres, and many farms are 5 and 10 times that size. This ongoing shift in farm structure raises a host of questions. How extensive is this structural change? What forces have accompanied and contributed to the shift to larger farms? What implications do these structural shifts have for family farms?

The shift of acreage to larger farms is part of a complex set of structural changes in crop agriculture. The number of mid-size crop farms has declined, while farm numbers at the extremes (large and small) are growing. Because of these changes, average farm size has changed little in the last three decades, even while cropland and crop production have shifted to much larger farms. The report documents the complex nature of modern farm structure and introduces statistics aimed at better tracking consolidation of land and production.

What Did the Study Find?

The report introduces a measure of midpoint acreage in which half of all *cropland acres* are on farms with more cropland than the midpoint, and half are on farms with less. Midpoint acreage is revealed to be a more informative measure of cropland consolidation than either a simple median (in which half of all *farms* are either larger or smaller) or the simple mean (which is average cropland per farm). Using this measure, ERS researchers found that:

- The midpoint acreage for U.S. cropland nearly doubled between 1982 and 2007, from 589 acres to 1,105.
- Midpoint acreages increased in 45 of 50 States and more than doubled in 16. The largest increases occurred in a contiguous group of 12 Corn Belt and Northern Plains States.
- Midpoint acreages more than doubled in each of 5 major field crops (corn, cotton, rice, soybeans, and wheat) and increased in 35 of 39 fruit and vegetable crops, where the average increase was 107 percent.

- The shifts were persistent, with a general pattern of increase between each Census of Agriculture conducted between 1982 and 2007. However, less comprehensive evidence from annual surveys suggests that the pace of consolidation slowed between 2007 and 2011, the last year for which data are available. Data from the 2012 Census will provide more definitive evidence of recent trends.

- Larger crop farms continue to realize better financial performance: average rates of return on equity increased with farm size in five major commodity categories analyzed in this report (corn, soybeans, wheat, fruits, and vegetables). In turn, larger farms utilize labor and capital more intensively, which provide them with the primary source of their financial advantage.

The long-term shifts in farm size have been accompanied by greater specialization—beginning with a separation of livestock farming from crop farming in the latter half of the 20th century. As crop and livestock production separated, full-time crop farmers could devote more time to crop production and manage more cropland. At the same time, the number of production and marketing contracts to govern the sale of products has increased. Contracts covered 32 percent of crop production in 2011, compared with 23 percent in the mid-1990s. Larger operations are more likely to use contracts, which can reduce the price and marketing risks faced by farmers.

Technology also plays an important role in driving increases in farm size, by allowing a single farmer to operate and manage more acres. Labor-saving innovations—from bigger and faster capital equipment to information technology, chemical herbicides, seed genetics, and changing tillage techniques—have substantially reduced the total amount of labor used in agriculture and facilitated the shift to larger crop farms.

Federal policies may affect farm structure through multiple channels, such as taxes, lending programs, environmental or food safety regulation, research and development funding, and commodity programs. Some effects are straightforward and fairly direct, while others are subtle and indirect. The impact of broad commodity policy is particularly complex. Some have argued that commodity and crop insurance programs, by reducing the financial risks faced by farmers, encouraged the adoption of organizational forms and capital equipment that spurred increases in farm size. It is, however, difficult to separate the impact of policy from technology itself and from other factors that affected farm risks.

While the above conditions may have facilitated the shifts toward larger farms, family farms continue to dominate crop agriculture. In 2011, 96 percent of U.S. crop farms were family farms, and they accounted for 87 percent of the value of crop production.

How Was the Study Conducted?

This study drew upon data from two main sources. The Census of Agriculture, conducted by the USDA's National Agricultural Statistics Service (NASS), provides comprehensive, historical, and publicly available data on consolidation and specialization trends. The study also relied on confidential farm-level data from the census accessed in a secure environment to ensure confidentiality, to generate measures of consolidation and farm size for the United States, and major commodities for 1982-2007.

The second primary source of data is the annual Agricultural Resource Management Survey (ARMS), jointly administered by NASS and ERS. The ARMS covers U.S. farming operations and their operators in the 48 contiguous States. The survey was used to supplement historic census data on consolidation with more recent annual developments, to provide data on financial performance among crop farms, to assess the role of family farms, and to provide evidence on the use of labor, capital, and various production practices among crop farms.

The study also used several additional datasets and publications from NASS, ERS, and other Government and private sources.

Farm Size and the Organization of U.S. Crop Farming

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Introduction

Large farms now dominate crop production in the United States. While most cropland was on farms with less than 600 acres in the early 1980s, today most cropland is on farms with at least 1,100 acres, and many crop farms are 5 and 10 times that size. This ongoing shift in control of farm resources and production raises a host of questions addressed in this report. How extensive is this structural change? Why is cropland moving to larger farms? Is the shift associated with other changes in farm structure, and will it continue? Do these structural shifts portend an end to family farms, and the emergence of corporate farms with diffused ownership and hired professional managers?

Economic Research Service (ERS) researchers measure and describe the nature of the changes that have occurred and assess the driving forces behind those changes, with an emphasis on technology, land attributes, farm organization, and public policy.[1] The shift of acreage and production to larger farms is ongoing and ubiquitous, occurring in most States and for most crops, including major field crops as well as fruits and vegetables. Because large farms continue to realize better financial returns, on average, than small and mid-size farms, it is reasonable to expect continued shifts of production and land to larger farms.

The complexity of U.S. farm structure makes the shift of acreage to larger farms hard to discern with common metrics. In recent years, the number of mid-size crop farms has declined sharply, while farm numbers at the extremes (large and small) have grown. As a result the size of the average farm (in acres) has changed little, but large farms have gotten considerably larger as they farm more of the country's cropland. The report documents the complex nature of modern farm structure and introduces statistics aimed at better tracking shifts of land and production.

Measuring Farm Size

In this report, farm size is defined according to acres of cropland operated by the farm, which is a transparent, easily understood measure for which statistics have been kept for many years. It is particularly well suited to the primary purpose of the report, assessing the consolidation of cropland into larger operations over time.

Farms may own cropland, but they also grow crops on cropland that they rent. The report defines farm size according to the cropland operated by the farm—that is, the cropland it owns, plus any that it rents, minus any rented to others.

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[1] An earlier ERS report (MacDonald and McBride, 2009) analyzed consolidation in livestock agriculture. Hoppe et al. (2010) document shifts of production to larger farms, using inflation-adjusted sales, while O'Donoghue et al. (2011) document broad changes in U.S. farm structure.

All cropland is not the same. Across regions, important differences exist in soil quality, topography, climatic conditions, and proximity to markets and urban areas. These differences affect the types of crops grown, the sales derived from a given amount of acreage, and the size of crop farms. To account for some of those differences in cropland attributes, ERS researchers measured and analyzed changes in farm size for States and for specific crops, in addition to national data.

About one-quarter of cropland is not harvested, and most of that is not planted to any crop.[2] Analyses of specific commodities rely on harvested acreage of the commodity because the data sources report acres harvested, rather than acres planted, on a consistent basis, while analyses of farm size include both harvested and non-harvested cropland. (See box: "Data, Current and Historic.")

Data, Current and Historic

ERS researchers supplemented Agricultural Resource Management Survey (ARMS) and Census of Agriculture data with information from several other National Agricultural Statistics Service (NASS) surveys, from ERS estimates, and from several other public and private sources. These sources are described in the report as they are introduced.

Census of Agriculture data. The report draws on publicly available data from the Census of Agriculture, administered by NASS. The census elicits information from all U.S. farms and is valuable for following long-term trends, since it dates back to 1840. It provides deep and comprehensive coverage of acreage and production for all U.S. States and for a wide range of commodities. The census was conducted at irregular 4-, 5-, and 10-year intervals until 1982 and at 5-year intervals since then. Information on the census can be found at www.agcensus.usda.gov/index.php.

However, besides publicly available census data, ERS researchers also used confidential farm-level census records for 1982-2007, accessed under an agreement with NASS that is designed to protect data security and confidentiality. The data were used to develop improved measures of consolidation for the Nation, States, and commodities.

ARMS data. The research also relies heavily on the Agricultural Resource Management Survey (ARMS), an annual survey of U.S. farms that is jointly administered by NASS and ERS. The ARMS is based on a representative sample of farms and their operators in the 48 contiguous States. The survey has been conducted annually since 1996, and the most recent data available for this report covered farm performance in 2011.

With a total national sample of just over 20,000 farms, ARMS cannot provide the comprehensive measures at the State and commodity level that the census provides, and it cannot match the long temporal span of the census. However, the survey gives more detailed data on farm finances, operators, resources, and practices than are available elsewhere. As an annual survey, it also gives greater and more recent temporal detail than the census.

—continued

[2]The 2007 Census of Agriculture recorded 406 million acres of cropland and 310 million acres of harvested cropland. Of the non-harvested cropland, 7 million acres represented planted cropland on which the crops failed, but most fell into three other categories: cropland in summer fallow (15 million acres); cropland used only for grazing or pasture (36 million acres); and cropland that was idled or used for cover crops or soil improvement (38 million acres). Land enrolled in the Conservation Reserve Program (CRP), Wetlands Reserve Program (WRP), or other conservation programs may be reported in harvested cropland, idle cropland, or woodland not pastured, depending on its use.

Data, Current and Historic—continued

ARMS comprises three phases, carried out at different times of the year. Phase I is a screening module, not used for research. Phase II, conducted in the fall of the reference year, targets up to two field crops. It focuses on field-level information, with questions on chemical use, resources and input use, production practices, and production outcomes. ERS researchers used Phase II data for a few selected topics, including tillage practices, information technology, and seed use. Most of the analyses are drawn from Phase III, which is conducted in the winter following the reference year and is aimed at all farms. Phase III focuses on production, input use, farm and operator attributes, and finances for the whole farm.

During most of the years covered in this report, Phase III includes five questionnaire versions. Version 5, shorter than the others, contains a core set of questions. Version 1 adds a detailed set of research questions on production and management practices and resource use to the core. Versions 2, 3, and 4—known as commodity versions—add commodity-specific questions to the core and are aimed at representative samples of commercial producers of the Phase II crops and one livestock commodity.

Most ARMS-based statistics in this report are drawn from the core questions that appear on all versions of the survey, while some are based on questions that appear only in Version 1.[1] As necessary, observations from several years are combined to generate larger samples (ARMS is not a panel, so different farms appear in different years). In the text discussion and table notes, distinctions are drawn between:

- Data drawn from Phase II and from Phase III;
- Data drawn from all Phase III versions and from version 1 only;
- Farms from a single year and farms pooled across 2008-2011.

Finally, NASS uses a stratified sampling strategy to improve the reliability of estimates in ARMS. That means that some farms have a higher probability of sample selection—larger operations are more likely to be selected than smaller ones, and selection probabilities also vary across geographic areas and commodity types. Population estimates are generated by weighting sample observations to reflect their varying selection probabilities.

Further information on ARMS, including questionnaires, can be found at www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices.aspx.

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[1]The survey is designed so that Version 1 records can be expanded to represent all farms; a separate set of weights allows the all-version sample to be expanded to represent all farms. Each commodity version carries additional weights to allow for expansion to represent the population of commercial producers of each commodity.

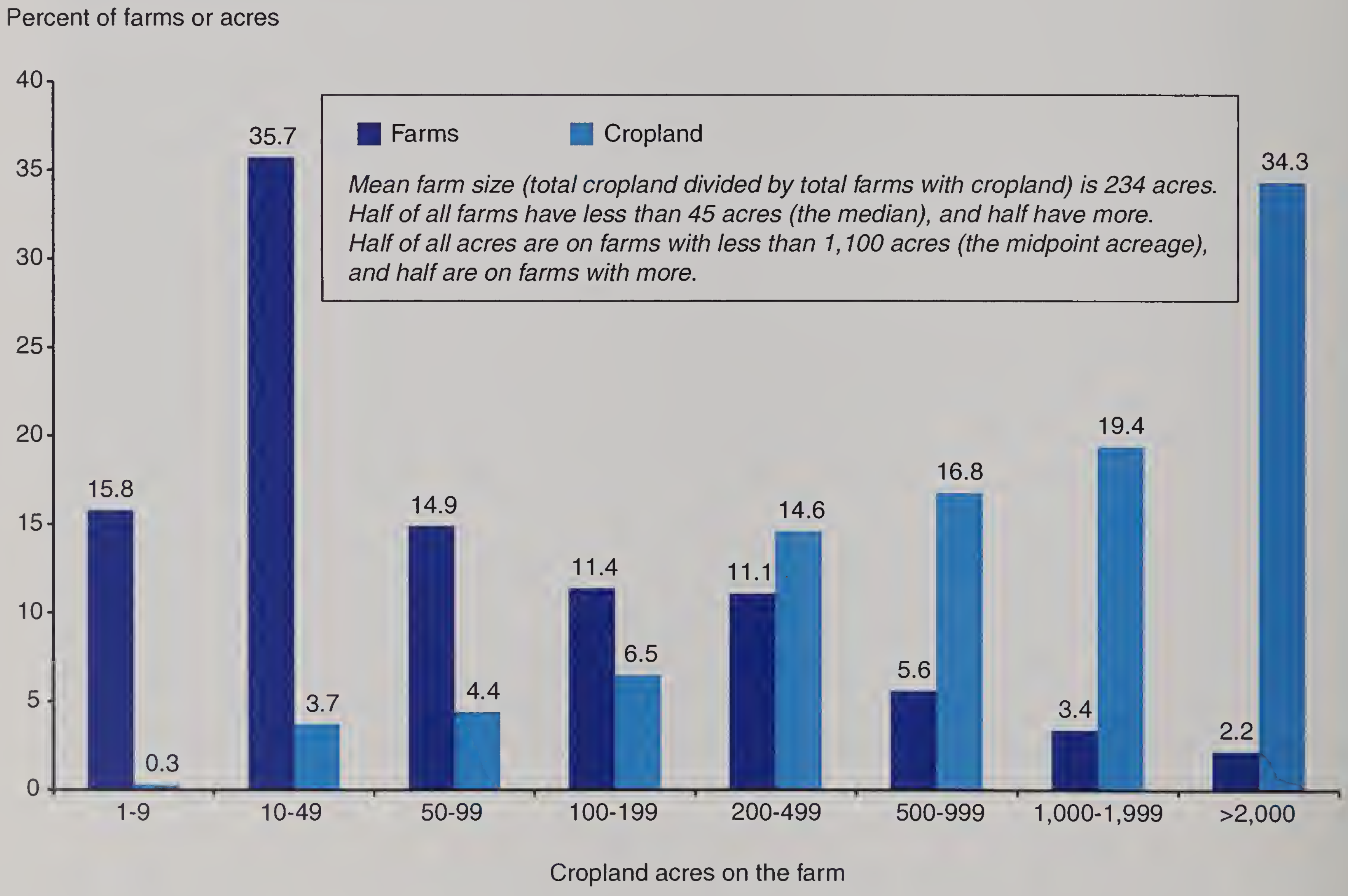
Consolidation of Cropland into Larger Farms

The average size of a U.S. crop farm has changed little during the past three decades. However, this seeming stability masks important structural changes in the complex U.S. farm sector. There are growing numbers of very small and very large farms and declining numbers of mid-sized farms. Cropland acreage has moved toward much larger farms.

Start with the complex size pattern of U.S. farms. In figure 1, based on 2011 ARMS data, farms and cropland acreage are sorted into eight cropland size classes frequently reported in Census of Agriculture publications. In that year, 391.6 million acres of cropland were divided among 1.675 million U.S. farms with cropland, for an average (mean) farm size of 234 acres. However, relatively few farms are near the average. Eighty percent of farms with cropland were smaller than the mean size, and 70 percent were less than half the mean size. The median farm size (at which half of farms were larger and half were smaller) was just 45 acres.

Similarly, little cropland is on farms near the average. Eighty-three percent of cropland was on farms that were larger than the mean size, and 71 percent was on farms that were more than twice

Figure 1
The size distribution of crop farms, 2011



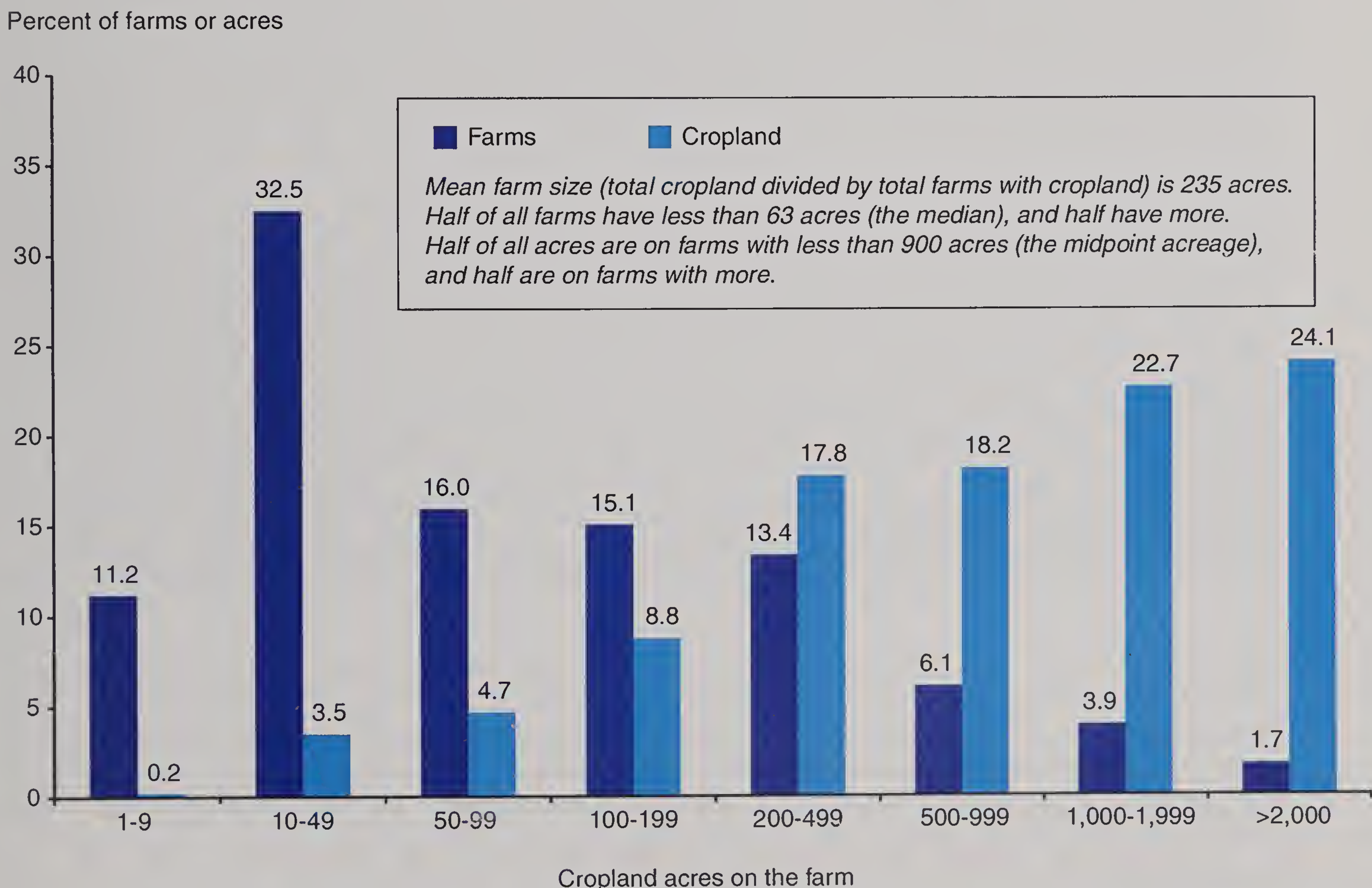
Note: Farm size is defined according to the cropland the farm operates—that is, the cropland it owns, plus any that it rents, minus any rented to others.
Source: USDA Agricultural Resource Management Survey, 2011.

the mean. The midpoint acreage—where half of cropland is on larger farms and half on smaller—was 1,100 acres.

Figure 2 reports the same data for 2001; together the two figures summarize a decade of structural change. The mean farm size was little different (235 acres), but the median farm size in 2001 (63 acres) was substantially larger than that in 2011. There were nearly 100,000 more farms with 1-49 acres of cropland in 2011 than in 2001, as the count of small farms in USDA statistics increased sharply. (See box: "The Increasing Number of Small Crop Farms.") Cropland moved in the other direction: the largest farms (at least 2,000 acres of cropland) accounted for 34.3 percent of cropland in 2011, up from 24.1 percent in 2001, and the number of farms with at least 2,000 acres of cropland increased during the decade. The midpoint acreage reflects the shift in cropland: it was 900 acres in 2001 (fig. 2), compared to 1,100 in 2011 (fig. 1).

Because of the complexity of changes in crop farm structure, simple measures of mean farm size are not very informative. Simple means and medians focus on the average farm, and the land operated by the average farmer. This report is focused on the use of cropland and must focus on the average acre of cropland, not the average farmer or average farm. The midpoint acreage effectively tracks cropland consolidation and will be used in this report.

Figure 2
The size distribution of U.S. crop farms, 2001



Note: Farm size is defined according to the cropland the farm operates—that is, the cropland it owns, plus any that it rents, minus any rented to others.
Source: USDA Agricultural Resource Management Survey, 2001.

The Increasing Number of Small Crop Farms

According to the Census of Agriculture, 872,000 farms harvested 1-49 acres of cropland in 1974, a decline of 70 percent from the 2.9 million farms in that size class in 1950. If the 1950-1974 trend had continued, there would have been less than 150,000 farms in that size class by 2011. However, the trend did not continue; the number of small farms, whether measured by sales or by acreage, declined much less rapidly after 1974 and began to increase after 2000.

In part, the survival and expansion of small crop farms may reflect farming opportunities as well as popular lifestyle choices by people who prefer to combine a rural lifestyle with modest crop or livestock production. A farmer can operate a small field crop operation on a part-time basis while also maintaining an off-farm job, or while drawing additional income from pensions and savings.[1]

However, how farms are counted also matters when considering trends in farm numbers. USDA, under the direction of Congress, has since 1974 defined a farm as a place that produces, or normally could produce, at least $1,000 worth of agricultural commodities in a year.[2] Because the definition is not adjusted for inflation, it will define more very small places as farms as farm commodity prices rise, and the Producer Price Index for Farm Products (Bureau of Labor Statistics) rose by 172 percent between 1974, when the definition was set, and 2011.

USDA/NASS has also made concerted efforts in recent years to better identify and track very small farms.[3] While these efforts improve survey methodology and provide more comprehensive coverage, their implementation indicates that some part of the observed increase in small farm numbers reflects better counting, not more farms. Because most of these farms are so small, with very limited production, their inclusion adds very little cropland or production to census aggregates.

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[1]By pooling ARMS Phase III records from 2008-2011, ERS analysts constructed a large sample of smaller, but still commercial, crop farms with 50-99 acres of grain or oilseed crops, and no livestock production. On average, operators of those farms report working 20 hours per week on the farm, and smaller operations could require less labor time.

[2]A place with less than $1,000 in sales in a year is classified as a farm if it has cropland or animal assets that could generate $1,000 in sales (the "normally could produce" part of the farm definition). There were 254,000 such farms in 1982, 232,000 in 1992, and 689,000 in 2007, a near-tripling in 15 years. For more on defining farms, see O'Donoghue, et al. (2009).

[3]For more on expanded efforts to track small farms, see the "Special Note Regarding the 2007 Estimates" on p. 31 in U.S. Department of Agriculture (2009).

The midpoint acreage is a median, but it differs from the median farm size that is also reported in figures 1 and 2. Technically, the midpoint acreage is the median of the distribution of *acreage* by farm size, as opposed to the more commonly reported median of the distribution of *farms* by farm size. (See box: "Midpoint measures in industry analyses.") The median farm size and the midpoint acreage differ widely: the 2011 median farm size was 45 acres, while the midpoint acreage was 1,100 acres, because they measure different concepts and because U.S. farms cover such a wide range of sizes.

Midpoint Measures in Industry Analyses

Midpoints have been widely used in industry analyses, often based on employment, where half of industry employees are at larger plants or firms, and half are at smaller (Florence, 1933; Scherer and Ross, 1990; Davis and Haltiwanger, 1991). As distinct from simple medians, they have been called Florence medians, referring to the first economics author to use them in 1933, and weighted medians, since they can be calculated by weighting each observation by its size (acreage, or employment in the most common applications). The measure is especially useful for size distributions that are highly skewed, with many very small operations while employment, acreage, or production is concentrated in a small number of large firms. Most U.S industries, including agriculture, are characterized by highly skewed size distributions. Acreage-based midpoints have been applied to the measurement of farm size by Lund and Price (1998), Key and Roberts (2007a), and O'Donoghue et al (2011). Lund and Price (1998) coined the midpoint usage.

ARMS data were used in figures 1 and 2 to summarize modern-day farm structure. ERS analysts used Census of Agriculture data to compare longer run trends in midpoint acreages and simple means during 1982-2007 (fig. 3).[3] The differences are striking. While mean farm size changed little between 1982 and 2007—from 221 acres to 241, or a 9-percent increase—the midpoint for cropland grew by 88 percent, from 589 acres to 1,105. The simple mean peaked in 1997, and declined thereafter, but the midpoint acreage rose steadily from 1982 through 2007. The differences reflect the shift of cropland to larger farms, even as increases in the number of very small farms kept the mean farm size from increasing substantially. While the average farm did not get much larger, acreage moved to much larger farms.[4]

The trend in the midpoint for harvested cropland does not exactly match that for cropland—the cropland measure rises steadily from 1982 to 2007, while the harvested cropland measure only rises after 1987—but the basic message is similar (fig. 3). The midpoint acreage for harvested cropland rose by 114 percent, from 500 acres in 1982 to 1,071 acres in 2007.

Shifts of cropland to larger farms mirror similar shifts of agricultural production from smaller to larger sales classes during 1982-2007. Hoppe et al. (2010) use Census of Agriculture data to show that farms with at least $1 million in sales (measured in 2007 dollars, and thus adjusted for changes in prices) accounted for 24 percent of the value of agricultural production in 1982 and 59 percent in 2007. Meanwhile the share held by small commercial farms, with $10,000 to $250,000 in sales, fell by two-thirds.

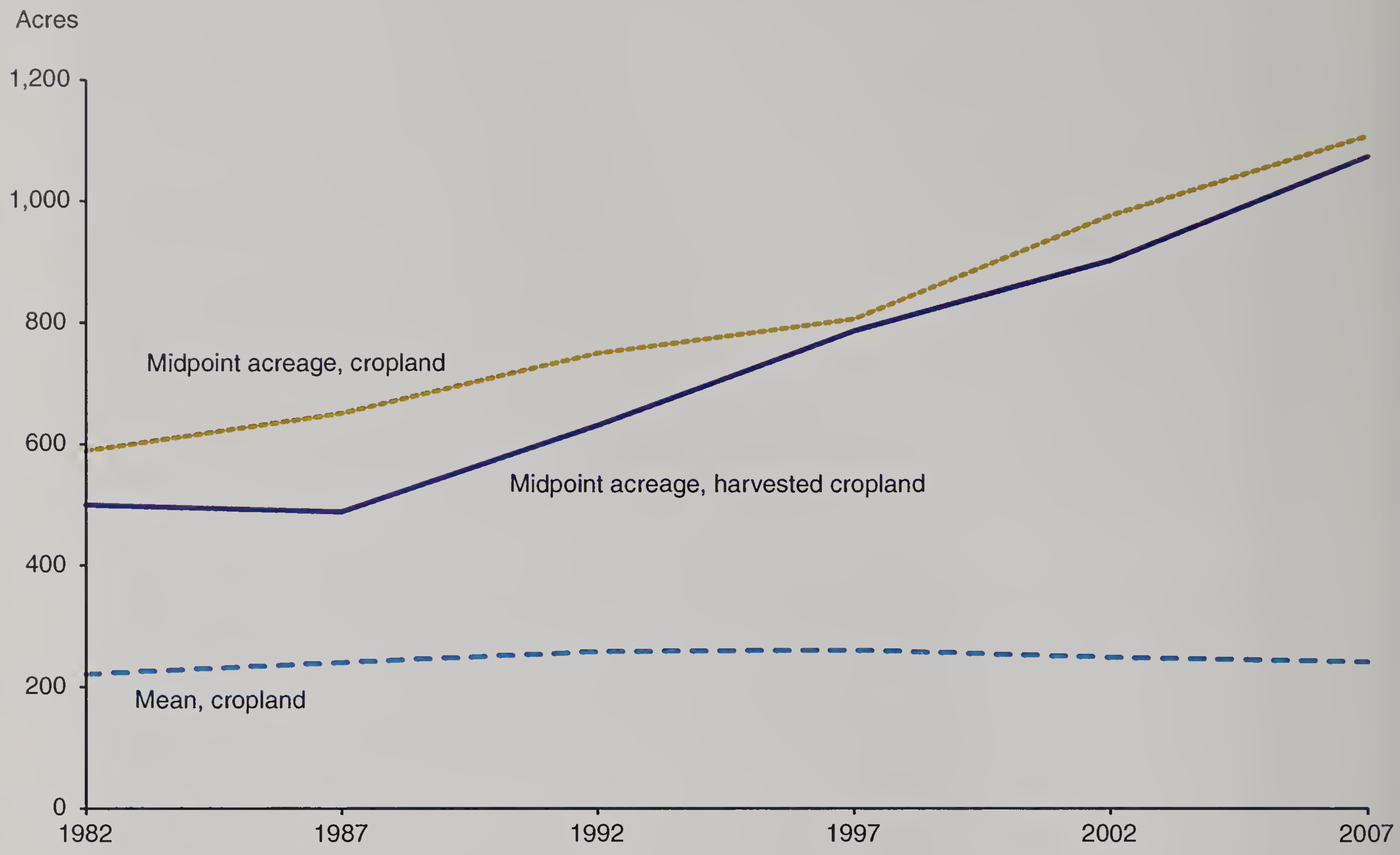
Cropland Consolidation in the States

The pace of cropland consolidation varied widely across States, although most saw substantial increases. Figure 4 reports State-by-State changes in the midpoint acreages for harvested cropland between 1982 and 2007. Harvested cropland shifted to smaller farms in 5 States, but shifted to larger

[3]The mean cropland measures are reported in Census of Agriculture publications, but the weighted median requires confidential record-level data, accessed by ERS under an agreement with NASS.

[4]The data can be used in another way to summarize consolidation. In 1982, 184,030 farms were as large as the midpoint farm size, and so operated half of U.S. cropland. In 2007, 86,531 farms were as large as the midpoint. Those "top-half" farms operated 1,215 acres of cropland, on average, in 1982 and 2,350 acres in 2007.

Figure 3
Three measures of average farm size



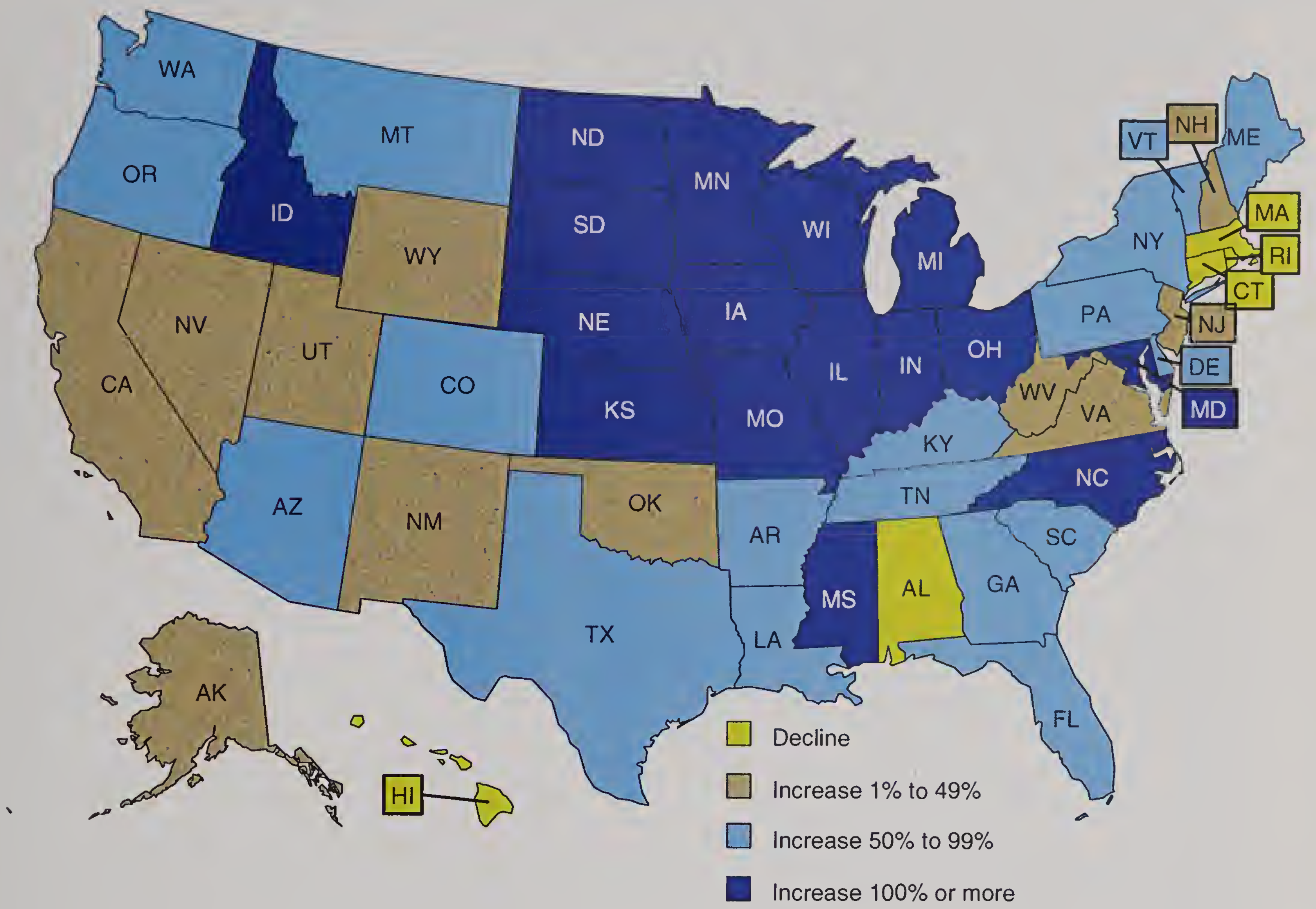
Note: "Midpoint acreage" defined—half of all cropland acres are on farms with more cropland than the midpoint, and half are on farms with less. "Mean" defined—total number of cropland acres is divided by the total number of farms with cropland.

Sources: Mean cropland is from the Census of Agriculture, while the midpoint acreages are ERS calculations from unpublished census of agriculture data

farms in the other 45, and midpoint acreages rose by more than 100 percent in 16 States. Declines occurred in Hawaii, where plantation agriculture that focused on pineapple and banana production was shifting to more diversified crop agriculture. Declines also occurred in Alabama and Southern New England. Increases of at least 100 percent occurred across a contiguous set of 12 Corn Belt and Northern Great Plains States, as well as Idaho, Maryland, Mississippi, and North Carolina.

A simple statistical analysis helps to summarize the patterns. Specifically, four attributes of a State's agricultural environment account for a substantial share of the variation in growth rates across States. (See box: "Accounting for Cross-State Differences in Consolidation.") Midpoint acreages increased more in areas where most land was cropland, with little land in forest, pasture, commercial, or residential uses. In such States, crop fields are more likely to be large and contiguous to one another, rather than scattered among other land uses. Consolidation also increased faster where population was less dense; denser populations make cropland consolidation more costly because of greater competition for land. Finally, midpoint acreages increased more in those States with high shares of harvested cropland relative to cropland, and where hay accounted for a smaller share of harvested cropland. Hay was more likely to be produced in regions with noncontiguous cropland and smaller fields, and it was also concentrated on hillier land that is often less suited to other field crops.

Figure 4
Changes in midpoint acreage for cropland, by State, 1982-2007



Note: Estimates are "midpoint acreages," for which half of all cropland acres are on farms with more cropland than the midpoint, and half are on farms with less.

The patterns of cropland consolidation do not rule out a role for organization, technology, or policy factors, and do not explain why consolidation is occurring, but the data suggest that the pace of cropland consolidation may vary with the presence of land and population attributes that constrain farm size.

Consolidation Among Specific Commodities

A closer look at consolidation among specific crops provides further insight into the trends observed in total cropland. Table 1 summarizes data on harvested acres for major commodities in 2007 and crop receipts for 2007, 1982, and 1950 and reveals three key details.

First, four crops (corn, hay, soybeans, and wheat) accounted for over 83 percent of harvested crop acres in 2007. Developments in these few crops drive national trends in midpoint acreages for all cropland combined.

Second, harvested acres do not correspond closely to cash receipts for crops. The three high-value categories—vegetables and melons; fruits, nuts, and berries; and greenhouse/nursery crops—accounted for nearly 37 percent of all cash receipts from crops in 2007 but less than 4 percent of harvested acreage. Producers of these commodities use labor and physical capital intensively to produce high sales per acre. Because acreage and receipts do not correspond

Accounting for Cross-State Differences in Consolidation

ERS researchers related cross-State differences in cropland consolidation to four attributes of a State's agriculture in 1982, the beginning of the period: the share of a State's cropland that was harvested, the share of harvested cropland that was in hay, cropland density (cropland as a share of land area), and population density (population per square mile). The two density measures are weighted averages across counties within a State, where the weights are cropland. All of the data were from the Census of Agriculture except for population density, which is drawn from Census Bureau (U.S. Department of Commerce) data. Density measures are weighted by cropland to measure density in those parts of a State where the cropland is located. For example, high population density in Manhattan (New York County) is irrelevant because none of New York State's cropland is in that county.

Consolidation was measured as the growth in a State's midpoint acreage for harvested cropland (the logarithm of the ratio of the 2007 to the 1982 midpoints), and consolidation was the dependent variable in an ordinary least squares regression with the four attributes as explanatory variables:

Variable	Mean	Standard deviation	Coefficient	t-statistic	Standardized coefficient
Intercept	-	-	-0.1997	0.87	
% harvested	71.5	12.4	0.0111	3.23	0.138
% hay	28.5	22.9	-0.0034	1.99	0.078
Population density	141.7	183.7	-0.0008	4.12	0.147
Cropland density	35.0	22.3	0.0041	2.16	0.091

Notes: The mean of the dependent variable was 0.51. The R^2 coefficient was 0.64. The standardized coefficient is the coefficient times the standard deviation (impact on the dependent variable of a 1-standard deviation change in an explanatory variable).

This simple model accounts for 64 percent of the cross-State variation in the growth in farm size. Growth in midpoint acreage is noticeably higher in States with high cropland density, low population density, high shares of harvested cropland, and low shares of hay. Each coefficient is statistically and substantively significant, and each explanatory variable shows substantial cross-State variation, to judge from their standard deviations.

Specifically, a one standard deviation reduction in population density is associated with a 0.147 log point increase in the growth rate of the weighted median—see the last column in the table for standardized coefficients. A one standard deviation increase in the share of cropland that is harvested (12.4 percentage points) is associated with a similar (0.138 log points) increase in consolidation. Cropland density and hay have smaller but still meaningful impacts. Relative to the sample mean (66.5 percent growth), a one standard deviation change toward slower growth in all four variables would reduce predicted growth to 6.6 percent, while a one standard deviation change to greater growth in all four would raise predicted growth to 162.2 percent. That range encompasses the growth rates of 42 of the 50 States in figure 4.

Table 1
Acreage and revenues, major crops, 1950-2007

Commodity	2007 Harvested acres		Percentage of all crop revenues		
	Acres (millions)	*Percentage*	2007	1982	1950
Field crops	**299.7**	**96.4**	**63.2**	**73.8**	**74.1**
Barley	3.3	1.0	0.5	1.1	1.9
Corn	86.3	27.7	22.7	17.7	9.2
Cotton	10.5	3.4	4.3	6.2	23.1
Hay	58.1	18.7	4.0	2.8	2.9
Oats	1.5	0.5	0.1	0.5	2.1
Rice	2.8	0.9	1.4	2.1	1.5
Sorghum	6.7	2.1	0.9	2.1	1.2
Soybeans	63.9	20.6	15.4	17.3	5.4
Tobacco	0.4	0.1	0.9	4.6	8.6
Wheat	50.9	16.4	7.6	13.6	14.0
Other field crops	15.5	5.0	5.4	5.8	8.3
High-value crops	**11.1**	**3.6**	**36.8**	**26.2**	**25.9**
Vegetables, melons	5.8	1.9	12.9	11.2	11.6
Fruits, nuts, berries	5.3	1.7	12.4	9.4	9.6
Greenhouse/nursery	na	na	11.5	5.6	4.7
All crops	**310.8**	**100.0**	**100.0**	**100.0**	**100.0**

Note: The corn and sorghum estimates exclude crops raised for silage, which are reported in "other field crops". The vegetable acreage estimates include harvested acreage of potatoes and dry beans, and field crops acreage estimates exclude them, to make them consistent with the cash receipts estimates.

Sources: Harvested acres are from USDA, National Agricultural Statistics Service, Census of Agriculture. Cash receipts are from Economic Research Service, www.ers.usda.gov/data/FarmIncome/finfidmu.htm.

closely, changes in farm size for high-value crops must be tracked separately, since their developments will be masked in aggregated acreage measures.

Third, long-term shifts have occurred in the mix of crops produced. Cotton, tobacco, and oats accounted for a third of all crop cash receipts in 1950. Those shares dropped sharply between 1950 and 1982, and by 2007, the three crops accounted for just 5 percent of cash receipts. The share held by wheat also declined, as the combined share of corn and soybeans rose by nearly 25 percentage points, and the shares held by the high-value commodity categories rose by 11 percentage points.[5]

[5]Acreage also shifted among field crops. Cotton and oats together combined for about 80 million acres (about 40 million each) in the late 1920s, compared to 12 million in 2007. The reduction in cotton acreage reflected slowing cotton demand, due to the introduction and spread of manmade fibers, combined with diminishing yields from traditional production areas in the Southeast and sharply rising yields in newer production areas in the Plains and West (Larson and Meyer, 1996). The reduction in oats reflected the 20th century shift from horses and mules, which were fed oats and hay, to tractors for farm work.

ERS researchers measured midpoint acreages for specific commodities and found that the shift to larger farms occurred in all major field crops and in most fruit and vegetable crops. These measures represent enterprises, the part of the farm producing a specific commodity. For example, a farm producing corn and soybeans has a corn enterprise and a soybean enterprise, and the midpoint acreage for corn reflects harvested corn acreage only, not harvested acreage of all crops on farms producing corn.

Field crop estimates are presented in table 2. The midpoint acreage for corn tripled from 200 acres in 1987 to 600 in 2007, a jump that was no doubt affected by the relatively high corn prices of 2007 (which led farms to increase corn acres at the expense of other field crops in 2007). But other crops also showed large long-term increases: midpoint acreages for cotton, rice, soybeans, and wheat all more than doubled between 1987 and 2007.

The exception is hay's midpoint acreage, which increased from 120 acres in 1987 to 160 acres in 2007, a much smaller increase than other field crops. Hay accounted for nearly 60 million acres, or 15 percent of all cropland. As noted above, States with substantial fractions of cropland in hay had less consolidation in all cropland.

Table 3 reports midpoint acreages for 20 vegetable commodities, while table 4 covers 19 fruit, tree nut, and berry crops. The commodities listed in the two tables represent 92 percent of all vegetable, fruit, tree nut, and berry acres in the 2007 Census of Agriculture.[6] A wider range of shifts is reported here—midpoint acreages for plums and cantaloupes declined between 1987 and 2007, and a few other commodities showed little change—but most showed large increases. Of the 39 commodities listed in tables 3 and 4, 30 showed increases of at least 50 percent between 1987 and

Table 2
Acreage shifted to larger field crop farms, 1987-2007

Commodity (field crops)	1987	1997	2007
	Midpoint acreage, harvested acres		
Corn	200	350	600
Cotton	450	800	1090
Rice	295	494	700
Soybeans	243	380	490
Wheat	404	693	910
Hay	120	140	160

Note: Midpoint acreages are the enterprise farm size, in harvested acres, at which half of all harvested acres are on larger enterprises, and half are on smaller enterprises.
Source: ERS calculations from unpublished Census of Agriculture records, 1987, 1997, 2007.

[6]This list expands on that provided in O'Donoghue et al. (2011), who also summarize several other elements of consolidation.

Table 3

Acreage shifted to larger vegetable and melon enterprises, 1987-2007

Crop	1987	1997	2007
	Midpoint acreage, harvested acres		
Asparagus	160	200	240
Beans, snap	221	225	323
Broccoli	440	780	1,000
Cabbage	113	162	300
Cantaloupe	400	431	388
Carrots	350	900	600
Cauliflower	240	400	400
Cucumber	115	250	505
Lettuce	949	1,461	1,815
Onions, dry	115	220	320
Peas	100	125	179
Peppers, bell	88	180	300
Potatoes	350	556	990
Pumpkins	20	24	30
Spinach	162	242	423
Squash	35	60	72
Sweet corn	100	173	250
Sweet potatoes	140	250	474
Tomatoes	400	589	820
Watermelons	80	100	150

Note: Midpoint acreages are the enterprise farm size, in harvested acres, at which half of all harvested acres are on larger enterprises, and half are on smaller enterprises.

Source: ERS calculations from unpublished Census of Agriculture records, 1987, 1997, 2007.

2007. The average increase across commodities was 107 percent.[7] All commodities listed in tables 3 and 4 showed increased midpoint acreages between 1987 and 1997, even if a few are small increases. In 1997-2007, 31 of 39 commodities showed increases, and 12 of those increased by more in 1997-2007 than in 1987-1997.

[7]The farm size distribution has become noticeably more skewed in fruits and vegetables, and midpoints provide information that is not apparent in simple means. Tomatoes provide an extreme but telling example. The 2007 census counted 25,809 farms, with 442,225 harvested acres of tomatoes, compared to 14,366 farms and 414,624 acres in 1997. Almost all of the increase in farm numbers occurred among farms with less than an acre of tomatoes: with new procedures designed to capture more very small farms, the 2007 census counted 17,536 farms with less than an acre of tomatoes, compared to 7,407 in 1997. The mean farm size—total acreage divided by the number of farms—fell from 29 to 17 acres, even as the midpoint acreage rose from 589 to 820 acres (table 3).

Table 4
Acreage shifted to larger fruit and nut enterprises, 1987-2007

Crop	1987	1997	2007
	Midpoint acreage, harvested acres		
Non-citrus fruits			
Apples	83	122	146
Avocadoes	40	54	40
Cherries, sweet	32	40	65
Cherries, tart	65	89	150
Grapes	205	306	320
Nectarines	70	120	186
Peaches	92	100	120
Plums; prunes	179	250	160
Pears	50	66	75
Citrus fruits			
Grapefruit	320	478	556
Lemons	176	177	176
Oranges	450	769	1,113
Tree nuts			
Almonds	203	292	450
Pecans	102	125	117
Pistachios	465	627	627
Walnuts	85	126	172
Berries			
Blueberries, tame	50	54	75
Cranberries	90	96	99
Strawberries	24	60	120

Note: Midpoint acreages are the enterprise farm size, in harvested acres, at which half of all harvested acres are on larger enterprises, and half are on smaller enterprises.

Source: ERS calculations from unpublished Census of Agriculture records, 1987, 1997, 2007.

To sum up, cropland consolidated onto larger farms in the last three decades. The shifts mirror similar shifts in farm size occurring in livestock. (See box: "Consolidation in Livestock Production.") Consolidation has been persistent, in that it has continued throughout the 1982-2007 period covered by the census data. It has been widespread across States and crop enterprises. Finally, the shifts have also been large—centering on a doubling of midpoint farm size over 20-25 years for national, State and commodity estimates.

Consolidation in Livestock Production

ERS researchers measured livestock consolidation with midpoint sizes based on herd inventory for dairy cows and annual sales or removals for other livestock. In 1987, the midpoint dairy herd size was 80 cows; by 2007, it was 570 cows. The change in hogs was even more striking, from 1,200 hogs removed in a year to 30,000. But consolidation was widespread: midpoint head sold for fed cattle doubled between 1987 and 2007, while those for broilers and cow-calf operations (cattle, less than 500 pounds) more than doubled.

Technology, in the form of economies of scale, played an important role in shifts to larger livestock operations, particularly in hog, dairy, fed cattle, and poultry production (MacDonald and McBride, 2009). Hog, poultry, and fed cattle production also became much more tightly integrated with processors over time, and changes in processor location, size, and contracting practices may have played a further role in livestock consolidation.

Commodity	Midpoints		
	1987	1997	2007
	Annual head removed or sold		
Livestock			
Broilers	300,000	480,000	681,600
Hogs	1,200	11,000	30,000
Fattened cattle	17,532	38,000	35,000
Cattle, <500 lbs.	50	65	128
	Milk cow inventory		
Dairy	80	140	570

Note: The midpoint is defined as the enterprise size, in number of head, at which half of animals are on larger enterprises and half are on smaller enterprises.
Source: ERS calculations from unpublished Census of Agriculture records, 1987, 1997, 2007.

Continuing Advantages to Size in Crop Farming

Larger crop farms perform better financially, on average, than smaller farms. The differences reflect lower costs per unit of production and not higher revenue. In turn, larger farms appear to be able to realize more production per unit of labor and capital. These financial advantages have persisted over time, which suggests that shifts of production to larger crop farms will likely continue in the future.

Larger farms realize higher rates of return on equity (table 5).[8] For each crop, profit measures generally increase from one acreage class to the next, and the differences are large in total. The estimates are drawn from 2008-2011 data, but the pattern holds for other years as well. These differences in profit performance do not stem from differences in revenue—larger grain and oilseed farms realize the same value of production per acre as smaller farms. The smallest vegetable farms (less than 50 acres) realize a higher value of production per acre than larger farms, but otherwise no apparent relation exists between size and revenue per acre at fruit and vegetable farms. These advantages must, therefore, arise from differences in farm production costs.

Labor hours per harvested acre decline sharply as harvested acreage increases for corn, wheat, and soybean farms (table 6).[9] Farms harvesting more than 2,000 acres use less than half as much labor per acre as farms harvesting fewer than 500 acres. Table 6 also reports the value of equipment and structures (assets) owned by the farm, per harvested acre. Assets per acre decline persistently as farm size increases; they are 35 to 50 percent lower for the largest farms than for those in the 250-499 acre class.

Table 7 reports the same measures for fruit and vegetable operations. Higher labor and capital use per acre in fruits and vegetables than in the field crops reflects the capital-intensive nature of fruit and vegetable production. However, the same general size relationship holds: labor hours per harvested acre decline as acreage increases, and capital per acre (the value of equipment and structures) also declines, except for labor for the largest size class (1,000 or more acres) among fruit operations. Moreover, the differences are large enough to be financially meaningful. In each commodity class, larger operations appear to be able to apply their labor and capital to more acres than smaller farms; with regard to capital, that suggests that larger farms get more hours of use in a year. Of course, this pattern may also reflect a more subtle relationship—that farms that are able to use labor and capital more intensively may also be better able to expand.

Leasing, Contract Labor, and Custom Services on Crop Farms

Tables 6 and 7 report on the labor that farming operations directly employ and the capital equipment that the operations own. But farms may access labor and capital in other ways:

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[8]The rate of return on equity measures the return on capital in the farm business (total assets minus total debt, or farm net worth). The numerator is net farm income, minus an adjustment for the opportunity cost of the unpaid labor and management time provided by farm operators and other unpaid workers. ERS researchers used class aggregates—total returns by all farms in a class divided by total net worth—to reduce the effects of extreme outliers, observations with near zero values of net worth, in financial data.

[9]On version 1 of the annual ARMS, respondents are asked to report hours worked on the farm by the farm's operators, the primary operator's spouse if he or she is not an operator, other unpaid labor (such as children, or spouses of secondary operators), and paid workers. The sample is, therefore, a subsample of the farms in table 5, with 2,087 grain and soybean farms and 1,471 fruit and vegetable operations.

Table 5
Larger crop farms realize higher average profit rates

Harvested acres	Farm specialization: Corn	Soybeans	Wheat	Fruits/nuts	Vegetables/ melons
	Class-average rates of return on equity, 2008-2011				
Less than 10	-	-	-	-1.4	-0.9
10-49	-	-	-	-0.2	2.7
50-99	-	-	-	4.1	-1.9
Less than 100	-0.9	-1.3	-2.6	-	-
100-249	1.2	-0.03	-0.6	5.4	8.1
250-499	2.9	1.1	0.6	3.8	17.8
500-999	4.8	1.7	0.4	7.1	8.9
1,000 or more	-	-	-	10.7	17.9
1,000-1,999	5.3	5.4	4.6	-	-
2,000 or more	8.0	8.2	5.5	-	-

Notes:

1. The sample consists of farms with no livestock production (crops only), and primary specializations in one of the five commodity classifications noted above. The primary specialization is the commodity accounting for the largest share of farm sales. Farms with livestock were omitted in order to simplify the analysis and focus on financial performance for crops.
2. The numerator of the rate of return on equity is net farm income, minus charges for unpaid operator labor and management contributions, while the denominator is net worth (assets minus debt). The table presents class averages—total returns across all farms in a commodity/acreage class, divided by total net worth in the class.
3. Pooling observations across years provides a larger sample size and more reliable estimates.

Source: Agricultural Resource Management Survey, Phase III, all versions, 2008-2011 pooled (17,351 observations: 6,619 in corn; 2,810 in soybeans; 2,079 in wheat; 4,492 in fruits; and 1,351 in vegetables).

- By leasing capital equipment and structures from dealers or from other businesses that rent out equipment and structures. Such assets are not recorded as assets of the farm business.
- By contracting for workers who are hired, employed, and paid through a contract labor provider.
- By contracting with custom service providers that bring their own labor, and may bring their own equipment, to perform field tasks such as spraying or harvesting.

These transactions afford several advantages, including flexibility to change the size of operations, avoidance of the financial risks of investment in expensive capital equipment, and the freedom to focus on specific farm tasks, while relying on custom providers' expertise for other tasks. If larger farmers use these services more than small farms, then an exclusive focus on capital assets and labor provided by the farm may understate the costs of larger operations and overstate their cost advantages over smaller operations.

Custom services are used extensively by many corn, soybean, and wheat operations, but (except in wheat) no apparent relationship exists between farm size and the likelihood that a farm will use

Table 6
Labor and capital on corn, soybean, and wheat farms

	Harvested acres					
	Less than 100	100-249	250-499	500-999	1,000-1,999	2,000 or more
	Mean hours per harvested acre					
Labor (all)						
Corn	38.6	12.3	7.8	5.7	3.5	2.7
Soybeans	45.7	10.4	7.3	5.8	3.8	3.0
Wheat	40.4	8.7	5.8	5.3	3.2	2.2
	Hired labor hours as a percent of total labor hours					
Hired labor						
Corn	5.0	2.9	4.6	10.2	16.9	31.2
Soybeans	2.7	5.2	7.4	14.6	16.4	36.0
Wheat	4.0	3.2	3.4	16.3	19.5	20.5
	Equipment and structures assets ($) per harvested acre					
Capital						
Corn	2,532	847	683	568	505	432
Soybeans	2,880	826	640	535	387	332
Wheat	3,325	588	396	320	278	242

Note: The labor and hired labor panels are based on version 1 only (2,087 observations), while the capital measures are drawn from all versions (11,508 observations).

Source: Agricultural Resource Management Survey, Phase III, 2008-2011 pooled.

custom services (table 8). However, larger farms are much more likely to use contract labor or to lease capital equipment and structures. This suggests that table 6 may understate the farm use of labor and capital when all sources are accounted for, and that it may therefore overstate the advantages of large farms regarding input use.

However, the bottom panel of table 8 shows that even though larger farms are more likely to incur expenses for each practice, dollar expenses fall sharply, per acre, as acreage increases. If there is a fixed set-up cost for these items, as well as a component of expenses that varies with acreage, then larger farms could have lower expenses per acre because they are able to apply the contracted inputs and custom services that they hire to more acres per hour of hire. Regarding the intensity of resource use, table 8 reinforces the message from table 6 that larger crop farms appear to be able to apply a given amount of capital and labor to more acres.

Producers of fruits and vegetables make extensive use of contract labor, leased capital, and custom services (table 9). In general larger farms are considerably more likely than smaller farms to use each of these practices, but there is no apparent relationship between farm size and the per acre expenses that are incurred for these services. Even when contracted and leased inputs are considered, larger fruit and vegetable farms are able to apply a given amount of labor and capital across more acres, on average, realizing lower costs per acre.

Table 7
Labor and capital on fruit, tree nut, and vegetable farms

	Harvested acres of fruits, tree nuts, and vegetables						
	Less than 10	10-49	50-99	100-250	250-499	500-999	1,000 or more
	Mean hours per harvested acre						
Labor							
Fruit/nuts	564.7	202.9	145.5	145.1	128.4	74.2	159.6
Vegetables/melons	849.3	204.4	150.9	98.5	59.9	46.4	32.8
	Hired labor hours as a percent of total labor hours						
Hired labor							
Fruit/nuts	7.4	23.6	43.0	52.1	51.2	58.2	55.6
Vegetables/ melons	5.1	14.2	37.7	41.7	43.4	47.6	61.4
	Equipment and structures assets ($) per harvested acre						
Capital							
Fruit/nuts	15,862	5,154	3,280	2,173	1,693	1,314	971
Vegetables/ melons	26,439	4,677	2,531	2,240	1,469	1,188	885

Note: The labor and hired labor panels are based on version 1 only (1,471 observations), while the capital measures are drawn from all versions (5,843 observations).

Source: Agricultural Resource Management Survey, Phase III, 2008-2011 pooled.

The financial estimates show continuing advantage to large farms, which should favor further consolidation. However, the pace of cropland consolidation also appears to have slowed in recent years. The midpoint acreage for cropland, measured with data from the Census of Agriculture, nearly doubled between 1982 and 2007, to 1,105 acres (fig. 3). Data from the 2012 Census have not yet been released, but the midpoint acreage estimated from the 2011 ARMS (see fig. 1) was 1,100 acres, just 1 percent greater than the ARMS-based estimate of 1,093 acres in 2007 (in fig. 3), and slightly below the 2007 Census estimate.[10] More definitive evidence will be available in data from the forthcoming 2012 Census of Agriculture.

Some recent developments in consumer demand may favor smaller family farms. For example, consumer and retailer interest in local food production is growing (Low and Vogel, 2011). Farms that produce for local markets are considerably smaller, on average, than other farms. In 2010, the midpoint acreage among crop farms that produce for local markets was 310 acres, compared to 1,100 acres for other crop farms. Among fruit and vegetable producers, the midpoint acreage was 168 acres, compared to 675 acres among other fruit and vegetable farms. Thus, shifts of consumption

[10]The Census of Agriculture data in figure 3 are based on all States, while the ARMS estimates are based on much smaller samples and exclude Alaska and Hawaii. However, ARMS estimates for the overlap years of 1997, 2002, and 2007 are quite close to Census measures. In 2007, the the midpoint acreage for Census was 1,105 acres, while that from ARMS was 1,093 acres.

Table 8
Use of contract labor, custom work, and leased capital in grain production

Practice and commodity	Harvested acres: Less than 100	100-249	250-499	500-999	1,000-1,999	2,000 or more
	Percent of farms using practice					
Custom work						
Corn	49.6	51.8	48.3	49.0	46.7	48.7
Soybeans	49.9	46.3	40.3	44.8	41.9	45.8
Wheat	31.3	40.7	45.7	49.9	52.8	60.0
Contract labor						
Corn	2.9	3.0	6.7	6.8	13.1	11.8
Soybean	1.9	3.2	4.5	5.7	9.8	17.5
Wheat	12.8	11.7	9.4	10.3	14.1	14.0
Leased capital						
Corn	7.9	7.2	14.6	17.5	23.4	37.9
Soybeans	4.6	12.1	12.7	12.8	12.6	23.9
Wheat	6.9	10.1	12.8	18.8	17.2	28.6
	Expense ($) per harvested acre for all three practices					
Expense						
Corn	31.13	21.76	15.10	12.51	12.07	10.86
Soybeans	25.57	18.90	13.58	11.23	7.05	10.56
Wheat	26.53	17.90	14.63	11.90	11.40	9.98

Notes: A farm is considered to "use a practice" if it has positive expenses for the practice, while expense per acre is the sum of expenses for custom work, contract labor, and leased capital.
Source: Agricultural Resource Management Survey, Phase III, all versions, 2008-2011 pooled.

to local markets, and hence to the farms that supply them, do appear to favor smaller operations.[11] However, farms that sell to local markets account for less than 5 percent of U.S. cropland.

Prices for farm products and for energy inputs were extraordinarily volatile in recent years (Baffes, 2013). In turn, that volatility increased the financial risks faced by farmers and by lenders. It also created uncertainty about the future path of Government policy, as policymakers and commodity groups debated the future orientation of crop insurance, commodity programs, and biofuels programs. The risk and uncertainty of the last several years may have slowed cropland consolidation, as farm operators and lenders pause to better understand the new financial climate.

[11]The data are drawn from version 1 of the 2010 ARMS (Phase III), where local producers were farms that had direct sales to consumers for human consumption, or that provided crops directly to retail outlets that in turn sold directly to consumers. Interest in organic products is also growing, but organic crop production appears to be concentrated on large farms; the midpoint acreage for farms with certified organic acreage was 1,968 acres in the 2010 ARMS.

Table 9

Use of contract labor, custom work, and leased capital in fruits and vegetables

Practice and commodity	Harvested acres						
	Less than 10	10-49	50-99	100-249	250-499	500-999	1,000 or more
	Percent of farms using a practice						
Custom work							
Fruits/nuts	25.8	41.7	56.5	56.7	63.1	70.3	71.6
Vegetables/melons	10.9	16.0	9.2	31.1	42.2	54.5	64.7
Contract labor							
Fruits/nuts	31.3	47.7	52.0	59.4	64.8	70.3	79.5
Vegetables/melons	3.1	13.8	17.6	29.0	36.0	33.3	56.3
Leased capital							
Fruits/nuts	7.2	9.8	21.3	22.4	30.6	39.0	44.6
Vegetables/melons	3.7	4.4	4.9	25.5	43.2	39.9	59.2
	Expense ($) per harvested acre for all three practices						
Expense							
Fruits/nuts	526	550	625	507	557	631	475
Vegetables/melons	234	122	83	119	203	202	239

Notes: A farm is considered to "use a practice" if it has positive expenses for the practice, while expense per acre is the sum of expenses for custom work, contract labor, and leased capital.

Source: Agricultural Resource Management Survey, Phase III all versions, 2008-2011 pooled.

Drivers of Consolidation

ERS researchers focused on three factors:

- **Technology**. Labor-saving innovations—in equipment, chemicals, seeds, tillage practices, and information technology—allow farmers to operate larger farms.

- **Changes in the organization of farms**. Over a long period, crop production has separated from livestock production as individual farms have focused on a few commodities and has concentrated in regions suited for adopting scale-increasing technology. Specialization and investment in costly capital equipment can be risky endeavors, and farmers also adopted methods of financing and transacting to reduce risks.

- **Government policy**. Federal initiatives affect farm structure through many channels—some lead to larger farms, while others support smaller farms. Some programs also affect the risks perceived by producers, and they can indirectly affect farm size by the way farmers adapt to these risks.

Drivers of Consolidation: Technology

Economists studying shifts in farm size often focus on the role of technology, and in particular on two concepts: scale economies and labor-saving technological change. Scale economies are said to exist if expansions of output lead to reductions in per-unit costs of production holding input prices constant.[12] Scale economies are technologically based, in that they arise from savings in input use, and not because a larger firm realizes lower prices for inputs.[13] They may be driven by certain fundamental physical relationships in production and may arise from the higher specialization in tasks that increased production can offer. They often arise because larger production runs may allow for the use of capital equipment, and more capital-intensive production, that would not be viable for smaller production runs.

Economies of scale matter for firm and plant size in non-agricultural industries. They also appear to matter, over certain ranges of production, in agriculture and particularly in livestock production (MacDonald and McBride, 2009; Miller et al., 1981). Nonetheless, most economists are skeptical that scale economies usefully explain increased farm sizes. Most farms remain fairly small, compared to firms in other industries, and crop production still covers a wide range of viable farm sizes. Moreover, because many large pieces of capital equipment are mobile and can be rented out to small operations for modest production runs, multiple small farms can effectively share equipment.

Instead of focusing on scale economies, analysts more often focus on labor-saving innovations, which are especially key for agriculture, where most farms are family-operated, with a certain amount of labor available for operation of the farm (Kislev and Peterson, 1982; Gardner, 2002; Cochrane, 1993). Innovations that reduce the amount of labor required for field operations allow

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[12]More specifically, the concept relates to the period of time long enough to allow the firm to vary all inputs.

[13]The term "pecuniary economies of scale" describes circumstances in which larger firms can obtain inputs at lower prices. In agriculture, such circumstances can apply when buying in large bulk quantities leads to lower unit prices, because the unit costs of shipping, storing, or processing a large order are lower. Examples include purchases of fertilizer and other farm chemicals, and purchases of transportation for products. While such pecuniary economies of scale can provide larger operations with advantages, they do not appear to have become more important, and do not appear to be important drivers of recent changes in farm size.

farming of more acres. Likewise, innovations that give farmers more accurate or timely information often increase the amount of land they can effectively manage. Labor-saving innovations do not have to explicitly favor larger farms to affect farm structure; instead all they have to do is facilitate the expansion of farms.

Equipment

The tractor remains a primary example of a labor-saving innovation. The first general-purpose tractor capable of operating among field crops was introduced in 1924, and its use spread until around 1960, with tractors steadily replacing horses and mules in field tasks. Olmstead and Rhode (2001) estimate that by 1960 the tractor had replaced 23 million draft animals, and the 79 million acres of land used to grow feed for them were reallocated to other uses. The tractor reduced the amount of labor time required to perform field operations, and required less labor time to maintain than draft animals. Olmstead and Rhode estimate that the tractor reduced the labor required to produce the agricultural output of 1960 by 1.7 million workers, about 24 percent of farm employment in that year. Finally, they estimate that tractor adoption increased average farm size by 58 acres, about 37 percent of the growth in average farm size between 1910 and 1960, as it allowed a single farmer to operate more acres.

The tractor wasn't the only labor-saving mechanical innovation introduced during the period. Mechanical harvesters, sprayers, and planters, designed for many specific crops, further reduced labor requirements (Street, 1957; Rasmussen, 1962, 1968; Reimund et al., 1981; Whatley, 1983; Calvin and Martin, 2010). In each case, total labor requirements were reduced, leading to reductions in the total farm workforce, but families that remained in agriculture could expand the farm operation with the labor and capital equipment available to them. In some cases, mechanical innovations required complementary biological innovations that created crops that could be more easily harvested mechanically.

Since the time covered by Olmstead and Rhode, tractors and other farm equipment have continued to get larger and faster, allowing individual farmers to manage yet more acreage. Bechdol et al. (2010) argue that a farmer could plant 40 acres of field crops in a day using the tractors and planters available in 1970, but 420 acres in 2005, and 945 in 2010, with larger and faster tractors hauling planters that covered far more rows than the 1970 version (table 10). For similar reasons, a farmer could harvest more than 12 times as much in a day in 2010 as in 1970.

Moving larger pieces of equipment between fields takes more time and expense, and larger pieces also require more setup time at fields. For these reasons, bigger and faster equipment is most valuable where fields are large, flat, and contiguous. Therefore, it is more valuable, and has greater effects on farm size, in the Western Corn Belt, the Plains, and the Delta, than in the Eastern Corn Belt, Appalachia, and the Northeast.

To see this effect, consider data on recent purchases of very large tractors—500 horsepower or more (which sell for an average price of over $250,000).[14] Between 2005 and 2011, 60 percent of those tractors were sold in just five Corn Belt and Plains States—Illinois, Indiana, Iowa, Minnesota, and North Dakota (table 11). Those are major agricultural States, but collectively account for just 27

[14]Because the Agricultural Equipment Manufacturers Association began reporting sales of tractors of 500 horsepower or greater for the first time in 2005, 2005-2011 sales are reported. The fact that the association did not report that category before 2005 itself indicates the shift to much larger and faster tractors.

Table 10

Changes in planting and harvesting machinery in field crops, 1970-2010

Year	Planting efficiency		Harvesting efficiency	
	Technology	*Outcome*	*Technology*	*Outcome*
1970	4 rows @ 2 mph	40 acres/day	4 rows, 12 hrs/day	4,000 bu./day
2005	16 rows @ 6 mph	420 acres/day	12 rows, 12 hrs/day	30,000 bu./day
2010	36 rows @ 6 mph	945 acres/day	16 rows, 12 hrs/day	50,000 bu./day

Notes: mph=miles per hour; hrs=hours; bu=bushels

Source: Bechdol, Gray, and Gloy (2010)

Table 11

Sales of large (500 horsepower or more) four-wheel drive tractors, by State, 2005-2011

State	Large tractor sales, 2005-2011		Cropland acres	Cropland density	Share of cropland non-harvest	hay
	Units	*Million $*	*Millions*	*Percent*	*Percent*	*Percent*
Top five, sales	**3,240**	**837.7**	**111.6**	**71**	**11**	**7**
Minnesota	1,119	287.2	21.9	69	12	9
North Dakota	864	223.0	27.5	69	20	11
Illinois	633	166.6	23.7	73	5	3
Iowa	381	97.8	26.3	77	10	5
Indiana	243	63.2	12.1	64	5	5
2nd five, sales	**893**	**229.1**	**80.9**	**43**	**27**	**22**
South Dakota	224	57.5	19.1	53	20	21
Texas	191	49.2	33.7	38	43	27
California	183	45.4	9.5	27	19	23
Michigan	160	42.2	7.8	43	12	17
Ohio	135	34.6	10.8	59	8	12
Other States	**1,246**	**317.0**	**214.0**	**40**	**29**	**29**
United States	**5,379**	**1,383.8**	**406.6**	**49**	**24**	**21**

Note: Cropland contiguity is the weighted average share of land in cropland, where the observations are counties and the weights are cropland.

Sources: Tractor sales are from Agricultural Equipment Manufacturers data provided to ERS, while cropland data are from Census of Agriculture.

percent of U.S. cropland, far below their share of large tractor sales. The next five most important States for large tractor sales (South Dakota, Texas, California, Michigan, and Ohio) accounted for 17 percent of sales and 20 percent of cropland, while all other States account for 53 percent of cropland and just 23 percent of large tractor sales.

Land attributes in the five leading States are different from other States. Much higher shares of cropland in those States are harvested than in other States, and much lower shares are planted to hay,

which is frequently grown on hillier and more marginal land. Moreover, cropland density is much higher in the top five States (71 percent of the land area is in cropland, on average, compared to 43 percent in the next five States and 40 percent for the rest of the country).[15] High cropland density indicates large and contiguous fields, where larger and faster tractors will be most effective.

Chemical Pesticides

Pesticides are substances used to control pests, including herbicides for weed control, insecticides to control insects, fungicides to control fungi and other disease pathogens, nematocides to control parasitic worms, and rodenticides for rodents. Pesticides can be synthetic or natural, and they are not the only means by which farmers might control pests. Farmers can control weeds through weeding, either by hand or with mechanical tillage, and they can control pests with management practices like crop rotations and interplanting.[16]

The use of chemical herbicides expanded between 1960 and 1980, from 35 million pounds of active ingredients to 469 million, as the proportion of acres treated with herbicides rose to over 90 percent for corn, cotton, and soybeans, and nearly 50 percent for wheat and potatoes (Fernandez-Cornejo, et al., 2013). Fernandez-Cornejo and Pho (2002) show that herbicide prices fell sharply compared to labor and machinery prices in this period, leading to two types of adjustments. First, farmers substituted existing chemical herbicides for other labor-intensive methods of weed control. Second, the relatively high prices for labor and machinery led to more research and development that would generate improvements in herbicides and other chemicals, leading to further substitution of chemicals for labor.

After 1980, the total pounds of herbicides applied stabilized and even declined for some crops, as the quality of herbicides improved. Newer substances more effectively controlled weeds with fewer applications, less toxicity, and shorter persistence in the soil (Fernandez-Cornejo and Pho, 2002; Fernandez-Cornejo et al., 2013). When adjusted for improved herbicide quality, prices of chemical methods of weed control continued to fall relative to labor and machinery prices after 1980, and farmers shifted to newer labor-saving herbicides, even as total herbicide applications stopped rising.

In their study using annual time series data for the United States covering 1948-1995, Fernandez-Cornejo and Pho (2002) find a strong labor-saving bias to the adoption of herbicides. They estimated that a 1-percent increase in the price of labor relative to herbicides would lead to a 0.23 percent increase in the ratio of herbicides to labor used in production, during the year of the increase. The long-run effect—covering longer term input substitution and the effects of induced innovation—was quite large; a 1-percent increase in the relative price of labor would lead to a 13.5-percent increase in the ratio of herbicides to labor use.

Substituting herbicides for labor increased the amount of cropland that a farm family could manage by reducing the labor and management time required per planted acre of a given crop. The impacts were likely sizable between 1960 and 1980, when herbicide use spread widely. Later herbicide

[15]Cropland density is the weighted average share of land in cropland, averaged across counties, where each county is weighted by its share of the State's cropland. The measure is designed to capture density in areas where the cropland is located.

[16]Pests often thrive on one crop, but not others. Farmers can, therefore, control pest populations by planting a succession of different crops in a field over time (rotation) or by planting a mix of different crops across a field (interplanting).

improvements likely allowed for further incremental expansions in farm size, intertwined with changes in crop genetics and tillage practices.

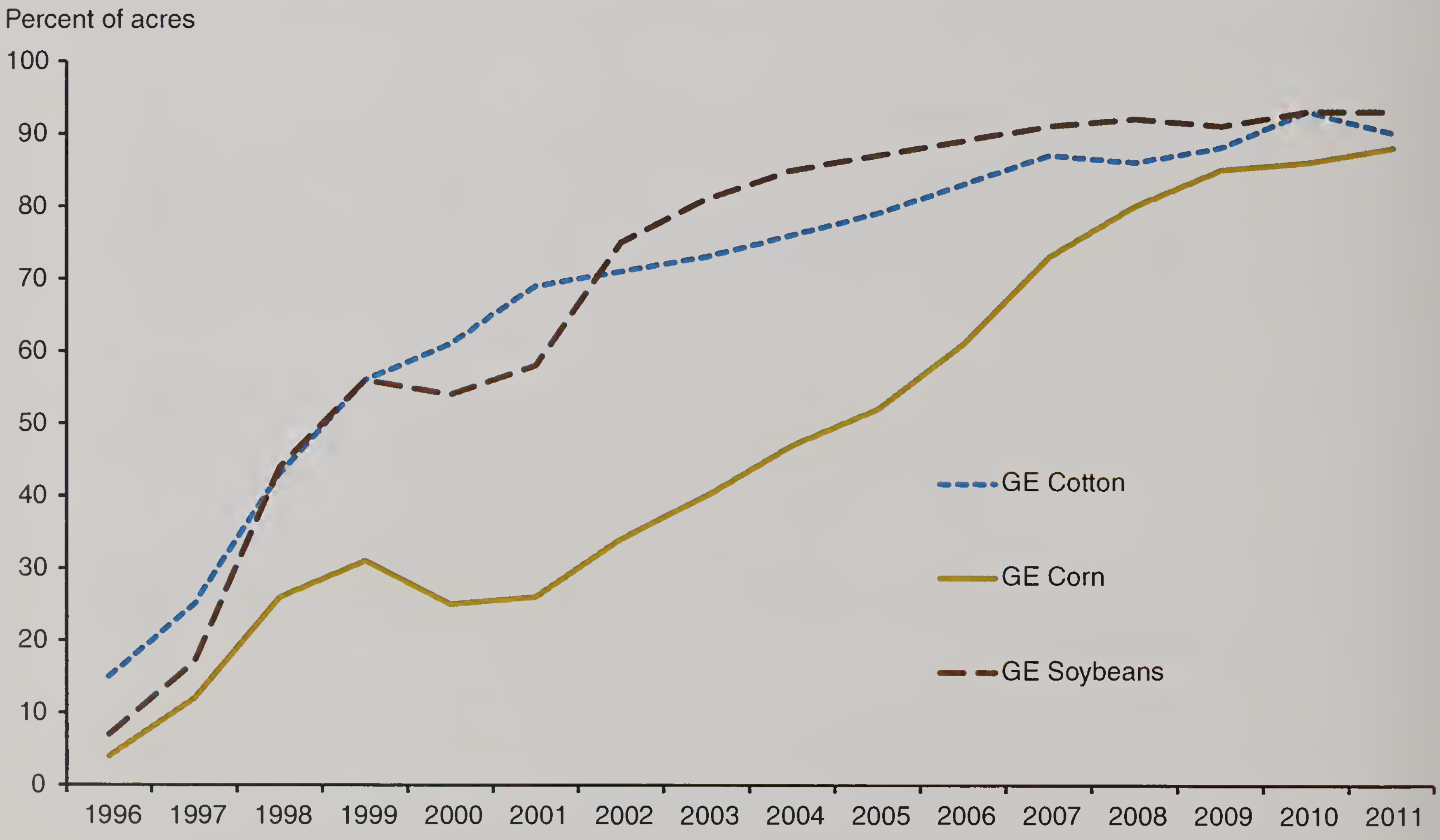
Genetically Engineered Seeds

Developments in seed genetics have also saved labor, either directly or in combination with other innovations (Gardner, 2002; Cochrane, 1993). For example, mechanical harvesters for processing vegetables, which greatly reduced labor hours, necessitated the complementary development of crop products that could withstand mechanical handling in harvest (Rasmussen, 1968; Schmitz and Seckler, 1970; Reimund et al., 1981).

More recently, the spread of genetically engineered (GE) seeds in corn, cotton, and soybeans (fig. 5) has affected farm production practices and the allocation of operators' time.[17] Herbicide-tolerant (HT) seeds, used in all three crops, allow farmers to apply one herbicide product at a post-emergent stage, thereby replacing several herbicides applied at different times (Fernandez-Cornejo, 2007). Use of HT seeds reduces machine and machine operators' time, as well as the time used to evaluate the need for and plan of weed management. Other GE seeds (Bt), used in corn and cotton, are pest-

Figure 5

Adoption of genetically engineered (GE) seeds in the United States



Source: Fernandez-Cornejo (2005) for 1996-1999; USDA NASS, *Acreage*, for 2000-2011

[17]GE seeds were also widely used on canola, papaya, and sugar beet acreage, and on some squash and sweet corn acreage, in recent years. However, these are minor U.S. crops, and the vast bulk of GE seed acreage is in corn, cotton, and soybeans.

resistant. In principle, they allow farmers to forego spraying pesticides, thereby saving machine and machine operator hours, although some farmers facing infestations may have simply accepted lower yields and did not use chemical pesticides. To the extent that GE seeds reduce the amount of time needed to plan and operate a given amount of acreage, they potentially free time to manage a larger farm.

Gardner et al. (2009) analyzed the linkages between labor hours used per acre and GE seed adoption, using ARMS corn, cotton, and soybean data collected in 2001, 2002, and 2003, respectively.[18] They find that adoption of HT seeds was associated with statistically significant reductions in labor hours in soybean and cotton fields, but not in corn fields, where HT adoption was still quite low in 2001.

ERS researchers used ARMS data for 2006 and 2008 to assess the relationship between GE seed adoption and hours of farm labor for corn, cotton, and soybean farms, while controlling for total cropland and the mix of crops on the farm, the use of capital equipment, and the use of custom services and contract labor, each of which can substitute for on-farm labor. (See box: "GE Seeds and Labor Time.")[19]

Results suggest that farms with acreage in HT crops realized substantial reductions in labor hours, per acre of land. For a farm with 1,500 acres of corn and soybeans, but no land planted to GE seeds, labor use on the farms would amount to 4,421 hours. With all of the land planted to HT traits, and none to Bt, the estimated labor hours would fall to 3,160 hours, freeing 1,261 hours for off-farm work, family time, or expanded farm production. Most farms don't face such stark choices between all or nothing: alternatively, the model estimates indicate that labor hours per acre would fall by 15.5 percent on farms with 75 percent of acreage in HT seeds compared to farms with 25 percent in HT. In contrast, the analysis shows no significant association between Bt adoption and labor hours.[20]

If GE seeds save management and labor time, farmers could use the freed labor time to work off the farm or to devote more time to family activities. Earlier research on the topic indicates that use of GE seeds was associated with increased earnings from off-farm employment, for a given size of farm (National Academy of Sciences, 2010). That research, driven by data availability, could access data on off-farm earnings but lacked direct data on labor hours, so researchers could not track whether farmers also used the freed time to expand their farming operation. This analysis described above shows a direct link to on-farm labor hours.

Genetically engineered seeds were commercially introduced in 1995, so they cannot account for changes in farm size before that time, and so far they have been used primarily in corn, cotton, and soybeans, so they cannot account for the ubiquitous increase in farm size among many crops. Their effect on corn, cotton, and soybean farms may be limited by the extent of acreage devoted to other crops or by time devoted to livestock production. Nevertheless, GE seeds may partly explain increased consolidation among field crop farms since 1995.

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[18]They used ARMS Phase II data, which elicit detailed information on activities carried out with respect to that field, including hours of labor expended in each activity.

[19]ARMS questionnaires for Phase III, version 1, included questions about GE seed use and about labor hours in those years.

[20]Over time, areawide use of Bt seeds may have reduced insect infestations for all corn, cotton, and soybean farms, thereby eliminating any differential labor-saving effect for Bt adopters.

GE Seeds and Labor Time

The 2006 and 2008 ARMS Phase III (Version 1) questionnaires included detailed questions on the use of genetically engineered (GE) seeds and on labor hours for the whole farm. ERS researchers selected a sample of farms from the 2 survey years, consisting of 1,798 operations with corn, cotton, or soybean production but no livestock (most raised other crops as well). Substantial cross-farm differences exist in the share of acreage planted to GE seeds, because of differences in the use of GE seeds for corn, cotton, and soybeans, and because of differences in the acreage of other crops planted on the farm.

ERS researchers sought to determine whether farms with higher shares of acreage planted to GE seeds worked fewer hours on the farm. To that end, a simple ordinary least squares regression was estimated, in which the dependent variable was the logarithm of total hours worked on the farm by all operators and other labor. Researchers controlled for total farmland acreage (in logs), the total dollar value of farm buildings and equipment (also in logs), the share of land that was harvested, dummy variables for the use of contract labor or custom services, a dummy variable to distinguish 2008 from 2006, and measures of the share of production originating in each of 15 field crop categories. The measures of GE acreage were the share of the farm's land planted to herbicide tolerant (HT) and to pest-resistant (Bt) seeds.

Labor hours were higher on farms with more land, more capital equipment, and a higher share of land in harvested acres. They were lower where the farm used contract labor or custom services and were lower in 2008 than in 2006. Hours varied with the mix of crops.

The coefficient on Bt was never statistically significant, but it was consistently positive, in this model and in alternatives analyzed for corn and cotton farms separately. Farmers plant seeds with Bt traits where there is a risk of insect infestation, and those risks may cause the farmer to have to use more hours (per acre) on other control practices. In any case, Bt seeds do not appear to reduce labor hours. In contrast, and consistent with the findings of Gardner, Nehring, and Nelson (2009), HT seeds reduce labor requirements per acre. The coefficient is negative, statistically significant, and large.

—continued

HT seeds were approved in 2011 for use in alfalfa, and other GE traits may be available in the future. Like other innovations, they can lead to increased farm size if they are labor-saving. However, other developments may reverse the impact of GE seeds on farm size. In recent years, resistance to glyphosate (the herbicide most commonly associated with HT seeds) has emerged among weeds. If farmers must return to older and more labor-intensive methods of weed control to manage resistance, the effect of GE seeds on farm size may slow and reverse.

Tillage Practices

"No-till" has become an important soil conservation practice in the United States. A no-till system leaves crop residue from the previous harvest on the soil, and soil is left undisturbed from prior harvest to planting, except for the injection of nutrients. By allowing for fewer machinery passes over fields and fewer machine operator hours, no-till saves labor, as well as capital and energy.

GE Seeds and Labor Time—continued

Regression results: Labor use on crop farms

Variable	Coefficient	t-statistic
Intercept	3.533	6.62
Log of land in farm	0.340	8.10
Percent of land harvested	0.519	6.41
Log of physical capital	0.187	4.35
Contract labor used (yes=1)	-0.379	1.43
Custom work used (yes=1)	-0.169	1.97
Bt acreage (percent)	0.167	1.13
HT acreage (percent)	-0.336	3.73
R^2	0.38	

Note: Dependent variable: log of annual paid and unpaid labor hours. Other variables include a dummy for 2008, and shares of acreage in each crop (corn, wheat, soybeans, cotton, peanuts, potatoes, barley, oats, tobacco, sorghum, hay, sugar cane and sugar beets, canola, other oilseeds, other crops). Observations are weighted to reflect sample selection probabilities, and standard errors are estimated using the delete-a-group jackknife method to account for complex sample design.

To understand the size of the effect, consider a farm in 2006 with 1,500 acres planted equally to corn and soybeans, with no custom work or contract labor, with $300,000 in equipment. With no land planted to GE seeds, the farm would require an estimated 4,421 hours. With all of the land planted to HT traits, and none to Bt, the estimated labor hours fall to 3,160 hours, freeing 1,261 hours for off-farm work, family time, or expanded farm production. This is an extreme example, given the 100 percent GE assumption, but the impact on hours is striking, as well as the implication that farmers with extensive acreage in HT crops could use those hours to noticeably expand farm size.

Estimates of the share of planted acreage under no-till are reported in table 12. The estimates cover five major field crops for 2000-2010.[21] For each crop shown, no-till shares are higher in later years, although the increases are modest. Horowitz et al. (2010) estimate that shares of planted acreage under no-till expanded at 1.5 percentage points per year between 2000 and 2009, when no-till covered 35 percent of planted acreage for eight major U.S. field crops (barley, corn, cotton, oats, rice, sorghum, soybeans, and wheat). Gardner et al. (2009) find that the use of no-till is associated with large and statistically significant declines in per-acre labor hours in corn, cotton, and soybeans.

HT seeds allow for easier use of no-till practices, and the recent spread of no-till owes something to the expansion of acreage planted to HT seeds. However, these phenomena are not entirely interdependent. While the highest share of no-till acreage is in soybeans, which had the earliest wide application of HT seeds, table 12 shows a rapid expansion of no-till in wheat, which had no HT seeds.

[21]Note that estimates are not reported for all years. USDA has not performed annual comprehensive surveys of tillage practices; instead, the ARMS covers field level practices of specific crops in different years.

Table 12
Use of no-till on planted cropland, 2000-2010

Crop	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Percent of planted acres in no-till system										
Corn	17	19	-	-	-	24	-	-	-	-	25
Cotton	-	-	-	15	-	-	-	20	-	-	-
Rice	5	-	-	-	-	-	12	-	-	-	-
Soybeans	31	-	35	-	-	-	45	-	-	-	-
Wheat	-	-	-	-	22	-	-	-	-	39	-

Source: Agricultural Resource Management Survey, Phase II, 2000-2010

Information Technology

Modern farm equipment embodies another set of innovations known as precision agriculture: management practices and information technologies (IT) that measure and manage intra-field variations in soil attributes, pest presence, product attributes, and production outcomes. Specific technologies include yield monitors that measure and map intra-field variations in yields at harvest; pest monitors that identify the presence of insects and fungi at spraying; GPS systems that map soil, yield, and pest data and transmit the information to vehicles in fields; and variable rate spraying and injection technologies that match the application of chemicals to the intra-field variations in yields, nutrients, and pest presence identified in the other technologies. These technologies, as well as auto-steering and guidance systems for tractors, hold the promise of reducing per-acre use of energy and chemicals primarily, but also of labor and management.

In fragile tree fruits like apples and oranges, researchers are experimenting with machines that locate and map fruit using a vision technology, combined with robotic machines that take information from mapping machines and use it to selectively harvest fruit as it matures (Calvin and Martin, 2011). These technologies, which may also apply to other crops, allow farmers to increase the value of production per acre, while reducing labor and management requirements. Other precision technologies, such as laser guidance for field leveling and drip irrigation, enhance water management.

Adoption of precision technologies has been growing: some type of precision technology was used on 58 percent of wheat acres in 2009, up from 14 percent in 1999; on 49 percent of corn acres in 2005, up from 35 percent in 1999; and on 45 percent of soybean acres in 2006, up from 31 percent in 1999 (Schimmelpfennig and Ebel, 2011).

Precision technologies can save on energy, chemicals, and nutrients, and they may also save management time if they allow farmers to gather and retain more accurate information in the course of field operations instead of in separate field visits. Because the innovations are embodied in expensive capital equipment, they also likely create scale economies: that is, given their expense, many of them are likely to only be economical on large operations that can spread their costs over large production volumes or through custom provision of services.

So far, most use of precision technologies has involved yield monitors, and widespread use of those has occurred recently, so precision technologies did not play a major role in the past growth of farm size (Schimmelpfennig and Ebel, 2011). Still, their role is likely to grow in the future if they are

labor-saving, and more importantly, if they provide farm managers with localized information that they would otherwise only obtain through time-intensive personal inspections.

Drivers of Consolidation: Farm Organization and Location

During the 20th century, crop production largely separated from livestock production, and crop farmers focused on producing a few commodities. Greater specialization provided a spur to increased size, and crop production also shifted toward regions suited for adopting scale-increasing technology. Specialization, and investment in costly capital equipment, can be risky endeavors, and farmers also adopted new methods of financing and transacting to reduce risks.

Farm Specialization

Most U.S. farms kept a variety of livestock in the first half of the 20th century, and they raised feed crops for their animals as well as cash crops for sale. While they became more specialized during the first half of the century, at least half of U.S. farms still had hogs, milk cows, or chickens in 1960 (fig. 6). The shift away from widespread and diversified livestock production accelerated after that date, and continued through 2000, when less than 10 percent of farms had chickens, milk cows, or hogs, and those that did usually specialized in one species.

The presence of livestock affects farm crop choices. In 1900, most farms grew corn, usually to feed to their own animals (fig. 7). As farmers ceased small-scale diversified livestock production, they also stopped producing feed for their small herds and flocks. By 2010, only one in six farms grew corn, and those farms usually specialized in crops, with no livestock.[22]

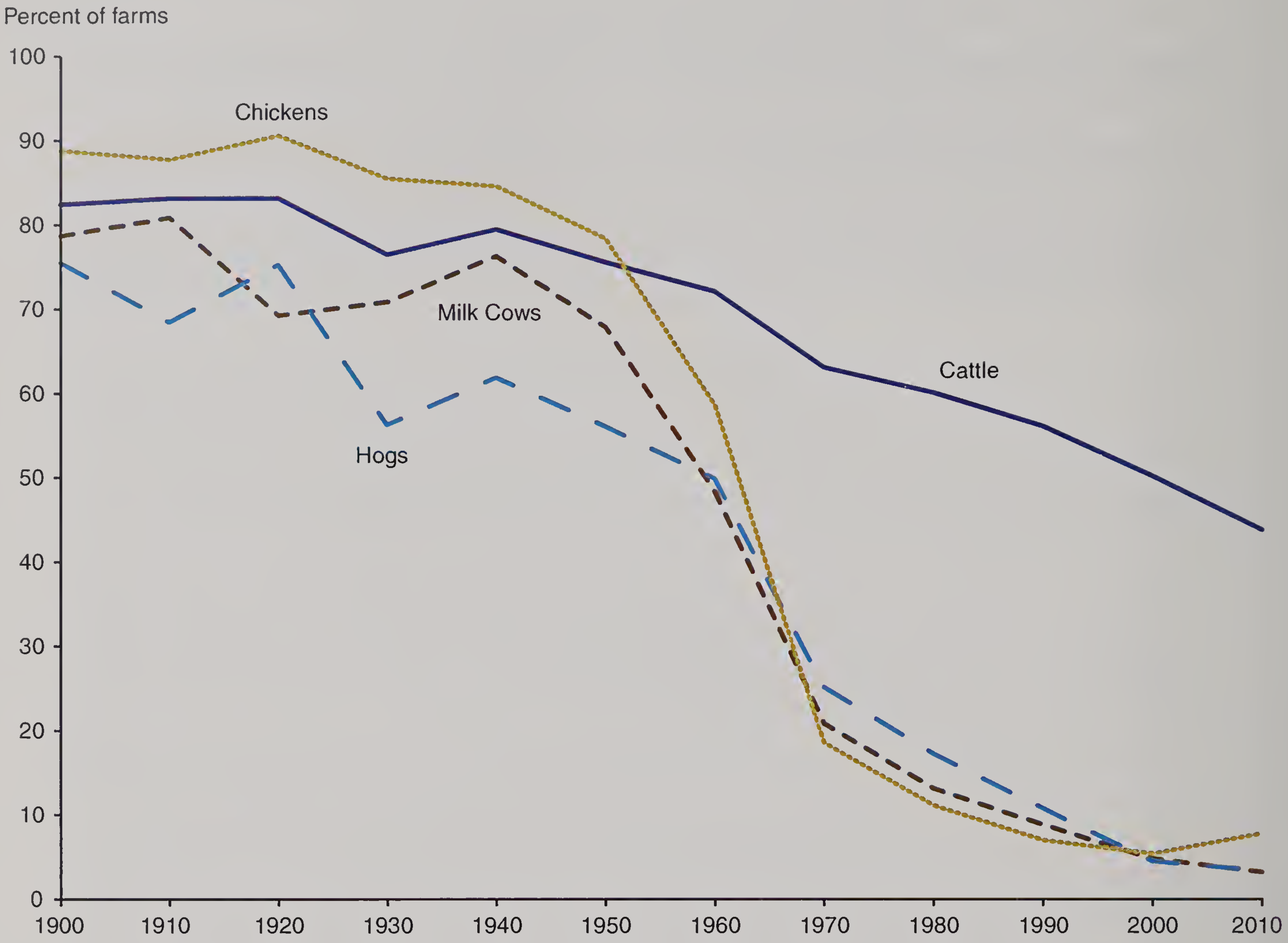
Livestock production concentrated onto fewer farms, and those farms focused on livestock, although most continued to grow some crops for sale and for manure utilization (MacDonald and McBride 2009). Today, almost all poultry production, and most pork and fed cattle production, rely exclusively on purchased feeds, while dairy production combines onfarm production with purchased feed. As a result, most crop production is concentrated on farms with no livestock, focusing on growing a few crops. Commercial markets for feed became deeper, with more transactions and greater volumes of feed sales, as less feed was produced for animals on the farm and more was sold by crop farms to intermediaries for processing and sale to livestock farms as feed components or complete mixes. Deeper markets provided more reliable services, a wider range of desirable feed attributes for purchase, and more certain market outlets for farmers.

Crop farmers who no longer pursued small-scale diversified livestock production had more free time available, which could be applied to work off the farm or to expanded crop production on more acres. As a result, changes in farm organization toward greater specialization also provided an impetus for crop farmers who wished to farm full-time to operate more cropland.

Once they left livestock production, crop farmers needed to decide on the mix of crops to produce. If all of a farmer's cropland has common soil and climatic attributes, then a single specific crop might be the most profitable for the farm, for a given combination of product and input prices. More specialized farms can also realize more intensive use of specialized equipment and structures, and

[22]See Gardner (2002) for more on increased specialization of U.S. farms during the 20th century.

Figure 6
Livestock on U.S. farms, 1900-2010



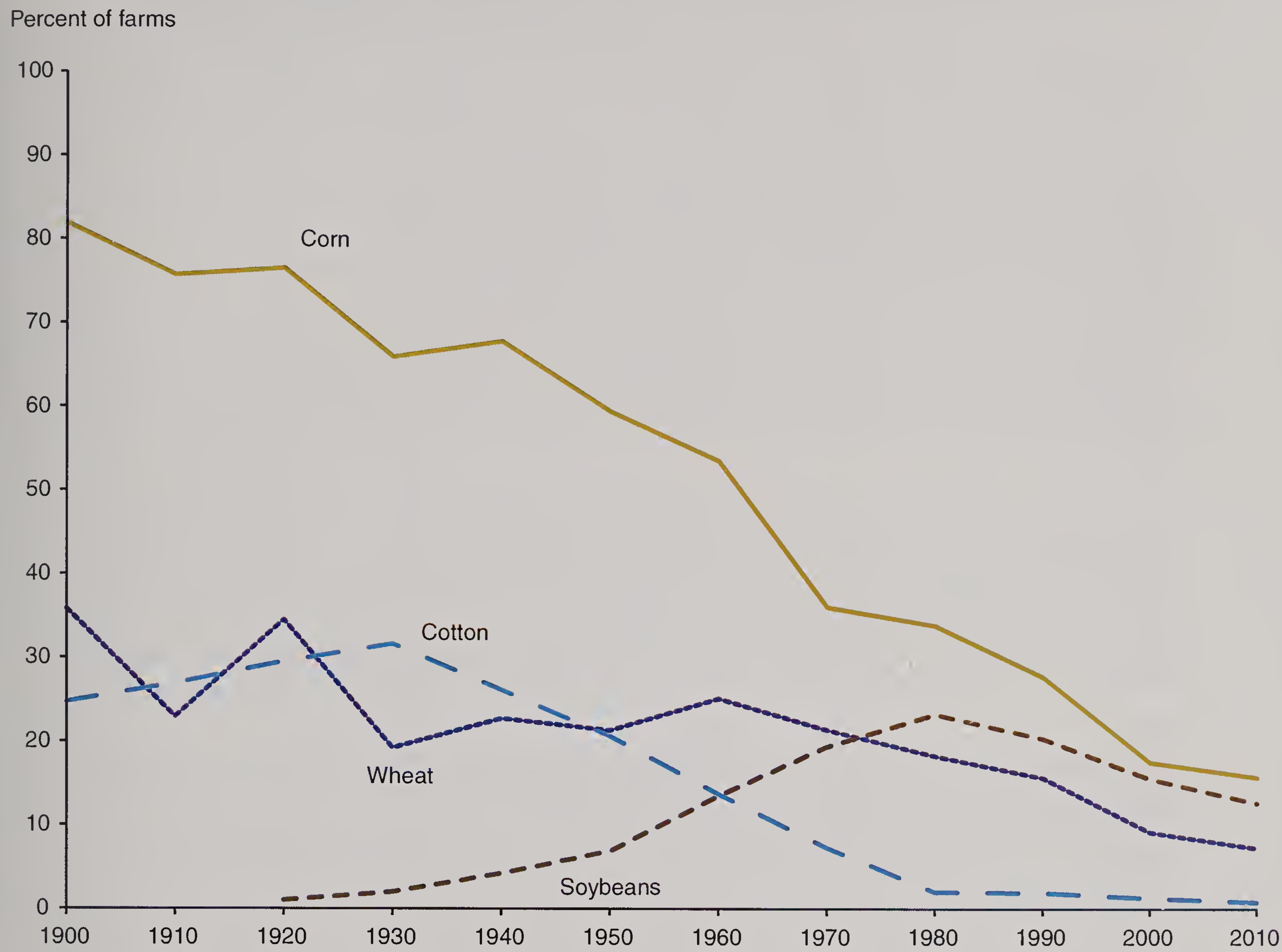
Source: Census of Agriculture, with data interpolated between Census years.

greater accumulation of crop-specific knowledge by producers, leading to reduced production costs (Holmes and Lee, 2012).

However, specialization carries risks. Specialization may create greater production risks from pest outbreaks, as well as economic risks from concentrated price shocks. Diversification across multiple crops might allow the farmer to reduce the financial risks of relying on one commodity, if commodity returns are not highly correlated across crops. Diversification can provide production advantages if farmers can reduce pest presence and improve soil attributes by rotating different crops through field. Finally, diversification may also allow farmers to more fully utilize their labor and capital over the course of a year, and thereby reduce production costs, if different crops are planted and harvested at different times of the year.

U.S. crop farms tend to resolve the trade-off between specialization and diversification by focusing on the production of a few crops—few farms are completely specialized, but few are highly diversi-

Figure 7
Selected field crops on U.S. farms, 1900-2010



Source: Census of Agriculture, with data interpolated between Census years.

fied. Table 13 summarizes product diversification on crop farms in 2011. It reports data for all crop production, and for production of 18 different crop categories.[23]

Twenty-seven percent of crop production occurred on farms that also had livestock—that is, 73 percent occurred on farms that specialized only in crops (table 13). The incidence varied across commodities—for example, barley, hay, oats, and sorghum producers frequently raise livestock (usually cattle), while little fruit and nut, greenhouse, sugar, rice, or vegetable production occurred on farms with livestock.

[23]The table reports estimates of the value of production for the 18 categories, and to construct this table ERS analysts drew on data for harvested acreage elicited in ARMS Phase III questionnaires for 21 crop categories: barley; canola; corn (grain and silage combined); cotton; dry edible beans/peas/lentils; fruits, nuts, and berries; hay (alfalfa and all other combined); nursery and greenhouse crops; oats; peanuts; potatoes; rice; sorghum (grain and silage combined); soybeans; sugarcane; sugarbeets; tobacco; vegetables (processing and all others combined); wheat; other oilseeds; and all other crops.

Table 13
Diversification in U.S. crop production, 2011

Commodity	Percent of 2011 value of crop production originating on farms with:					
	1 crop	2 crops	3 crops	4 crops	More than 4 crops	Livestock
All crops	22	30	22	15	11	27
Barley	4	19	33	17	27	43
Canola	0	11	25	20	44	23
Corn	4	42	25	15	14	34
Cotton	12	18	22	25	23	18
Fruits/nuts	84	8	2	1	5	7
Hay	33	23	16	13	15	42
Nursery/greenhouse	87	8	3	1	1	3
Oats	1	3	24	39	33	55
Peanuts	3	16	30	22	29	20
Potatoes	17	13	20	16	34	19
Rice	30	28	23	11	8	6
Sorghum	1	19	28	24	28	51
Soybeans	3	42	23	17	15	33
Sugar beets	0	2	16	40	42	25
Sugar cane	83	7	8	2	0	8
Tobacco	30	10	18	25	17	40
Vegetables/melons	29	15	16	16	24	9
Wheat	15	19	27	20	19	35

Note: Crops are those listed in section B of the ARMS Phase III questionnaire: barley; canola; corn (grain and silage combined); cotton; dry edible beans/peas/lentils; fruits, nuts, and berries; hay (alfalfa and all other combined); nursery and greenhouse crops; oats; peanuts; potatoes; rice; sorghum (grain and silage combined); soybeans; sugar beets; sugarcane; tobacco; vegetables (processing and all others combined); wheat; other oilseeds; and all other crops.

Source: 2011 Agricultural Resource Management Survey, Phase III, all versions.

Twenty-two percent of crop production occurred on farms that produced only a single crop commodity, while 30 percent occurred on farms with two crops. Only 11 percent occurred on farms with five or more crops. Note that the analysis uses just 21 crop categories, and that some categories—such as vegetables or fruits—contain many specific crops. Table 13 only captures farm diversification across categories, so production of multiple vegetable crops is not captured in this measure.

Farms that produce major field crops rarely specialize in just one—note that less than 5 percent of corn and soybean production occurred on farms with a single crop (that is, only corn or only soybeans). Two-fifths of production was on farms with two crops (typically corn and soybeans, in rotations designed to maintain soil quality and limit pest infestations), while another quarter occurred on farms with three crops. Moreover, over a third of corn and soybean production was on farms that also had livestock production; on many of these farms, livestock manure is "fed" as fertilizer to crops, while the crops are sold and feed is purchased.

Substantial production of hay (33 percent) and tobacco (30 percent) occurs on farms that grow only those crops, but there is also a considerable amount of production on farms with four or more crops. Sugar cane, fruits and nuts, and nursery/greenhouse operations are highly specialized, but farms can and often do grow multiple fruit or nursery crops.

Contracts and Crop Production

Greater specialization can expose farms to greater financial risks. Today, many farm product transactions are organized through contracts between farmers and buyers that are reached prior to harvest (or before the completion of a production stage, as in the case of livestock), and that govern the terms under which products are transferred from the farm. Contracts can reduce financial risks for farmers by providing a more secure outlet for production and by reducing the farmer's exposure to input and output price fluctuations. Consequently, contracts may also expand the supply of credit available to producers by providing lenders with the assurance of outlets for farm products, thus reducing the risks of lending (Key, 2004). In each case, the expanded use of agricultural contracts may facilitate shifts to larger farm operations.

In ARMS, ERS distinguishes two types of agricultural contracts: production and marketing contracts. *Production contracts*, used primarily in livestock production but also common in vegetables and horticulture, specify services to be provided by a farmer for a contractor who owns the commodity while it is being produced. Contracts cover (1) specific services to be provided, (2) the manner in which the farmer is to be compensated for the services, and (3) specific contractor responsibilities for provision of inputs.

Marketing contracts are far more important in crop production. They focus on the commodity as it is delivered to the contractor, rather than specify the services to be provided by the farmer. They set a commodity's price or a mechanism for determining the price, a delivery outlet, and a quantity to be delivered. Forward contracts, with a specific price set at the time of agreement, are one type of marketing contract. But other types, often of longer duration, specify a method or formula for determining prices, rather than a specific price, at the time of agreement. The pricing mechanisms may limit a farmer's exposure to the market price risks. They usually specify minimum acceptable levels of various product attributes, and they often specify price premiums to be paid for desired levels of attributes (such as oil content in corn), thereby providing incentives to produce higher cost but desirable product varieties.

Contracts covered 40 percent of all agricultural production in 2011 and 32 percent of crop production, where their use is growing; contracts covered 28 percent of crop production in 2001-02 and 23 percent in the mid-1990s (MacDonald and Korb, 2011). Earlier data on contract use in agriculture is sparse, but the Census of Agriculture reports that contracts covered 11 percent of all agricultural production in 1969, which suggests that there was an important shift toward greater reliance on contracts since then.

Does contract use affect farm size and structure? Larger crop farms are more likely to use marketing contracts (see also Key, 2004). Table 14 compares attributes of farms that use marketing contracts to those that do not, in each of eight major crop categories. Contracting farms tend to be larger: they operate substantially more farmland than farms that do not contract; they have higher values of production; and they harvest more acres of each crop. Corn, soybean, and wheat farmers who contract tend to place a little over half of their crop production under contract, often in multiple

Table 14
Contract and noncontract U.S. field crop producers, by commodity, 2011

Crop and contract status	Whole farm attributes		Reference crop acres	Share under contract	
	Farmland acres	Value of production ($)		Reference crop	Other crops
	Mean values				
Corn					
Contract	911	690,148	409	53.6	40.7
Noncontract	545	338,795	208	0.0	4.7
Cotton					
Contract	1,593	1,271,321	669	81.6	56.9
Noncontract	1,276	812,944	413	0.0	16.3
Fruits/nuts					
Contract	170	619,268	109	96.2	31.3
Noncontract	91	217,220	41	0.0	2.8
Peanuts					
Contract	1,509	1,037,972	240	99.0	55.8
Noncontract	665	544,094	127	0.0	15.1
Rice					
Contract	1,587	1,234,746	593	85.7	52.6
Noncontract	1,197	767,206	413	0.0	29.9
Soybeans					
Contract	920	652,975	380	56.3	43.1
Noncontract	513	320,672	196	0.0	5.3
Vegetables/melons					
Contract	1,386	1,631,856	136	96.2	34.0
Noncontract	126	209,557	24	0.0	0.0
Wheat					
Contract	468	872,068	468	59.7	45.9
Noncontract	271	484,596	271	0.0	11.0

Note: The estimates are drawn from farms with any harvested acreage in the listed crops, with 5,109 observations for corn, 693 for cotton, 1,445 for fruits and nuts, 204 for peanuts, 284 for rice, 5,107 for soybeans, and 3,590 for wheat. The estimate for the share of other crops under contract is based on farms that produced other crops in addition to the reference crop.

Source: 2011 Agricultural Resource Management Survey, Phase III, all versions.

contracts with different buyers. They also combine contracting with cash sales, sales from storage, on-farm feeding, and financial hedging in a broad risk-management strategy. Other contract producers commit almost all of their crop production to the contract, usually with a single buyer. In each commodity, farmers who use contracts for one crop also contract extensively for their other

crops, while noncontract producers rely on cash markets. For large-scale producers, contracts form part of a portfolio of marketing strategies to manage risk.

The Location of Crop Production

As livestock and feed production separated, they became concentrated in different regions, and changing regional specialization played a role in changes in farm size. States in the Northeast, Appalachian, and Southeast regions held 18.5 percent of all cropland used for crops in 1950, and 11.2 percent in 2007, a 7.3 percentage point decline that in part reflected declines in cotton and tobacco acreage (table 15). Corn Belt and Northern Plains States increased their share of U.S. cropland from 43 percent to 50 percent.

These long-term acreage adjustments reflected the organizational shifts noted earlier, and also reflect important regional shifts in commodity orientation: as farms became more specialized, Corn Belt States concentrated more heavily on the production and sale of feed crops, and livestock production moved from the Corn Belt to Mountain, Southeastern, and Southern Plains (Hart, 2003). Two regional belts of States illustrate the shifts (table 16).

In 1950, crops accounted for less than a third of cash receipts from farming in the four Corn Belt States of Illinois, Indiana, Iowa, and Ohio. Most cash receipts came from sales of livestock fed on the crops grown on those farms. Corn and soybeans accounted for 63 percent of receipts from crop sales. Sixty years later, livestock sales were no longer dominant: crops accounted for 68 percent of total cash receipts, and corn and soybeans for 93 percent of crop receipts. Those four States

Table 15
Regional shifts in cropland, 1950-2007

Item	1950	1982	2007
Total acres (millions)	383.2	382.8	334.9
	Percent of U.S. cropland used for crops		
Region:			
Northeast	5.5	3.6	3.3
Appalachian	6.8	5.0	5.1
Southeast	6.2	3.8	2.8
Delta	4.8	5.0	4.5
Lake States	10.6	10.4	10.8
Corn Belt	21.0	22.6	24.7
Northern Plains	22.2	24.5	25.2
Southern Plains	11.4	9.6	9.2
Mountain	7.0	9.8	9.2
Pacific	4.5	5.7	5.2
All	100.0	100.0	100.0

Note: "Total acres" refers to cropland used for crops (and harvested, failed, or left fallow), and excludes cropland used only for pasture or left idle.
Source: ERS Major Lands Uses, http://www.ers.usda.gov/Data/MajorLandUses/

Table 16
Shifts in agricultural specialization in selected States, 1950-2010

Item	1950	1980	2010
		Percent	
Crop share of region cash receipts			
Corn Belt 4	29	61	68
Corn and soybean share of crop receipts	63	89	93
Southern 6	72	51	40
Cotton and tobacco share of crop receipts	71	32	18
Share of U.S. livestock cash receipts			
Corn Belt 4	26	16	13
Southern 6	5	10	17
Share of U.S. crop cash receipts			
Corn Belt 4	13	23	22
Southern 6	18	10	9

Note: "Corn Belt 4" is Illinois, Indiana, Iowa, and Ohio, while "Southern 6" is Alabama, Arkansas, Georgia, Mississippi, North Carolina, and South Carolina.

Source: ERS Farm Income database (www.ers.usda.gov/Data/FarmIncome/finfidmu.htm)

accounted for a quarter of all U.S. cash receipts from U.S. livestock production in 1950, but that share fell by half over the next 60 years as beef and dairy production moved out of the region. Those changes reflected a movement of acreage into corn and soybeans, but also an expansion of hog and cattle production in other regions and the rapid growth of U.S. poultry production, carried out largely in the South.

A near mirror shift occurred in a belt of six Southern States of Arkansas, Mississippi, Alabama, Georgia, South Carolina, and North Carolina (table 16). Crops accounted for 72 percent of cash receipts in 1950, and most of that reflected just two crops—cotton and tobacco. By 2010, crops fell to 40 percent of cash receipts as cotton and tobacco declined and poultry and hog production expanded. Together, those States accounted for 17 percent of all U.S. livestock receipts in 2010, compared to 5 percent in 1950. While feed crops are grown in those States, they import much of their feed from the Corn Belt.

The interregional shifts in cropland affected crop farm size. Cropland declined in regions with hilly topography and mixed land use—cropland interspersed with forests, residences, and commercial uses—and shifted toward regions with flatter land and more of the land base devoted to crops. The latter were more suited to the types of equipment that could allow a farmer to manage a much larger farm. As a result, interregional shifts in cropland supported the impacts of new technology in driving production to larger farms.

Drivers of Consolidation: Government Policies

Federal policies may affect farm structure through multiple channels. Some programs may increase consolidation, while others may reduce consolidation. Some effects are straightforward and fairly direct, while others are subtle and indirect.

Tax policies can affect prices for capital goods, thereby affecting purchases of farm machinery and structures. Durst (2009) notes that the treatment of agriculture in the tax code, through capital cost recovery provisions, has effectively reduced the costs of capital to agriculture. LeBlanc and Hrubovcak (1986) found that changes in tax policy had important impacts on the cost of capital and equipment investment in agriculture. If lower tax rates lead to lower costs of capital, and if farmers respond by purchasing more capital equipment, then tax policy can enhance technology's effect on farm size.

USDA lending programs extend credit to farmers who may not be able to obtain loans through commercial channels, and some programs also provide subsidized interest rates. To the extent that these programs either help new small farms become established or prevent existing small farms from closing, they can limit cropland consolidation.

USDA research programs may also affect the availability and prices of technologies, and hence, farm sizes. Schmitz and Seckler (1970) analyze one well-known example, the development of the mechanical tomato harvester. Government provided about 40 percent of the total research and development expenses for the harvester, which once introduced led to the replacement of farm labor with capital and thereby induced a shift to larger operations. Similarly, Fernandez-Cornejo and Pho (2002) argue that public and private research programs to produce improved herbicides generated a labor-saving innovation that allowed farmers to operate larger farms with the hours saved from weed control.

Regulatory policies aimed at environmental or food safety targets may alter the relative costs of large and small farms, thereby inducing changes in farm structure. For example, Sneeringer and Key (2011) showed that, after the Environmental Protection Agency imposed size-based thresholds for regulation of concentrated animal feeding operations (CAFOs) under the Clean Water Act, newly constructed operations tended to enter the hog industry at sizes just under the regulatory threshold. During this period, scale economies in hog production were leading to much larger operations (Key and McBride, 2007), so the CAFO rules induced some farmers to constrain farm size, compared to what they would have developed absent the regulation.

Issues related to farm structure played a role in the design of the Food Safety Modernization Act (FSMA) of 2011, which gives the Food and Drug Administration new enforcement authorities to improve compliance with risk-based food safety standards. The rules apply new standards for growers of fruits, vegetables, nuts, mushrooms, herbs, and sprouts. When the rules are fully implemented, they will impose higher costs on farms not already in compliance. The bill includes new requirements for testing and reporting that would likely have imposed higher costs, per unit of production, on smaller farms. The Act exempts certain farms from compliance—those that sell the majority of their products directly to consumers or retail outlets within 275 miles or within the same State, and that have annual sales of less than $500,000.

Federal commodity programs have been a key focus of discussion among analysts of farm consolidation. The Government operates broad-based commodity programs that affect a range of field crops, as well as several programs aimed at individual commodities. The programs' designs create varied impacts on farm structure.

In the case of peanuts and tobacco, marketing quotas regulated prices and production until the early 2000s and appear to have limited farm size (Dohlman et al., 2009; Kirwan et., 2012). Marketing quotas set limits on aggregate supply by giving quota owners the exclusive right to sell a set amount of the commodity at or above a support price within a geographic area. Tobacco producers without quota could not sell the commodity, so tobacco marketing quotas also fixed annual supply, while peanut producers without quota faced marketing restrictions that left them selling at lower prices to the export and crush markets (Dohlman et al., 2009). Because support prices were set well above cash expenses, quotas became valuable assets that could be exchanged.

The transfer of quota rights among quota owners was restricted. In most States, tobacco quotas could not be exchanged across county lines. Peanut restrictions were more complex, but transfers of quotas across State lines were generally forbidden, and transfers across county lines were limited. The programs had been in place with some adjustment since 1930 for tobacco and the 1940s for peanuts. Since then, production of other crops has shifted to much larger farms while also undergoing a series of locational adjustments. Because quotas made such adjustments more difficult and costly, they limited geographic adjustment, growth in farm size, and productivity growth.

The peanut quota system was eliminated in 2002, and the tobacco system was eliminated in 2004. Each policy change featured buyouts of quota owners. Peanut production came under broad-based commodity program support, while all Federal support for tobacco producers was ended.

Each crop saw rapid shifts of production to larger farms and different regions after marketing quotas were eliminated; the shifts to larger farms were much stronger than any previous trends in the sectors, and much stronger than shifts in other commodities. In 2001, just before the buyout, the average peanut farm operated 860 acres in total, with 120 in peanuts; just 6 years later, mean farm size had increased to 1,525 acres, with 227 in peanuts (Dohlman et al., 2009). Average peanut yields per acre rose by 21 percent.[24]

In flue-cured tobacco, mean tobacco acres per farm increased from 33, at the time of the buyout in 2004, to 84 in 2007, while mean farmland acres rose from 566 to 906. Burley tobacco farms are much smaller, but average burley tobacco acreage rose from 5 to 10.5 acres, and mean farm size rose from 191 to 247 acres (Dohlman et al., 2009). In a detailed study of Kentucky tobacco operations, Kirwan et al. (2012), using Census of Agriculture data, found that tobacco farm productivity increased by 44 percent between 2002 and 2007 (a period encompassing the policy change) after declining by 7 percent in 1997-2002. They found that average tobacco farm size doubled during the buyout period, and that structural change played a major role in driving the increase in productivity.

Other factors also contributed to the changes. Many older tobacco producers anticipated the buyout and remained in tobacco farming to be eligible for transition payments made to active growers. As a result, farm closures were lower just before the policy change, and higher just after, than they would have been without transition payments (Dohlman et al., 2009). In peanuts, market prices and planted peanut acreage fell after the buyout, and those shifts had independent effects on peanut acreage per farm. However, in each case, the design of the quota systems suggested that they would have limited farm size, and the rapid shifts of production to much larger farms in the aftermath of quota elimina-

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[24]The increase in mean farm size does not mean that individual tobacco farms all increased acreage; rather, many very small farms shut down, and tobacco acreage and production shifted toward larger farms in different locations.

tion provide strong evidence that the programs effectively did limit farm size, aside from other more transitory factors.

Broad-Based Commodity Programs

Broad-based USDA commodity programs direct their support primarily to producers of certain field crops: wheat, feed grains, cotton, rice, and oilseeds, and some programs also cover pulse crops, honey, and wool. A redesign of the programs in the mid-1990s made direct payments (DPs) to farmers based upon the acreage they historically enrolled in commodity programs and the historic crop yields from that acreage. The programs also provide countercyclical payments (CCPs), on the same production basis, when market prices fall below target levels and provide for marketing assistance loans, based on current production, that offer support when prices are below target levels. Marketing assistance loans, which effectively set minimum prices that farmers can expect to receive for their crops, have been part of commodity programs in one form or another since the 1930s, while DPs and CCPs were more recent developments.[25]

Broadly speaking, payments tend to follow production: farms with greater production of a program commodity—either because they have more acreage of the commodity or higher yields on their acreage—receive greater total payments. There are some limits on the aggregate payments that farm operators can receive, but the limits have not affected many existing operations (White and Hoppe, 2012). Despite receiving higher overall payments, larger farms do not receive systematically higher payments on a per-acre or per-bushel basis than small farms receive, nor do commodity payments represent a higher share of their gross income. Moreover, payments tend to be capitalized into land values, and to raise cropland rents, thus benefiting landlords and raising renters' costs. They do not provide an obvious direct impetus to increase farm size.

However, several authors have argued that commodity programs contributed indirectly to the explosion of agricultural productivity growth, and the concurrent and ongoing shifts of production to larger farms that followed the New Deal introduction of the programs, because of their effects on farm financial risks, farmer behavior, and lenders. Cochrane and Ryan (1976, p. 373) argued that commodity programs "provided the stable prices, hence price insurance, to induce the alert and aggressive farmers to invest in new and improved technologies and capital items, and the reasonably acceptable farm incomes and asset positions to induce lenders to assume the risk of making farm production loans."

Clarke (1994) offered a specific application of the Cochrane-Ryan hypothesis focused on the diffusion of the tractor in the 1920s and 1930s. She developed a model of the value of adopting tractors on farms, and argued that farms with more than 100 acres of land should have adopted the tractor during the 1920s. Yet many did not, and Clarke argues that the riskiness inherent in farming at the time prevented adoption; before the introduction of New Deal commodity programs, farm prices and incomes varied widely from year to year. In addition, credit markets were focused on short-term loans, and many farmers did not have access to credit—in more modern language, they were "credit-constrained." Farmers, therefore, hesitated to make the long-term financial commitment necessary to purchase durable goods like tractors.

[25]S. 954, the Agriculture Reform, Food, and Jobs Act of 2013 (being considered in Congress as of this writing), would eliminate DPs and CCPs, while retaining marketing assistance loans and expanding crop insurance.

The introduction of New Deal commodity programs, according to Clarke, reduced farmers' financial risks by setting floors below which commodity prices would not fall. New Deal lending programs made credit more available and also gave competition to commercial lenders, who reduced rates and broadened terms in response to the competition. Improved credit and reduced financial risks led farmers to purchase capital goods and also to make cash outlays for intermediate goods like commercial fertilizers, prepared feeds, and hybrid seeds. With increased and more assured demand for capital equipment, manufacturers invested in improvements to equipment.

Clarke (1994) and Cochrane and Ryan (1976) argued that commodity programs complemented and accelerated the spread of labor-saving technology, by hastening the adoption of capital equipment, and may also have affected the types of farmers who adopted new equipment. That position is not undisputed; others see a far greater role for technological advances, often fueled by Government investment in research, in driving productivity growth and farm structure during the New Deal and thereafter.[26] Moreover, farm commodity programs have changed considerably since the period that they analyze. In particular, commodity programs since the 1980s have been built around DPs to farmers, and income stabilization, instead of supply controls aimed at supporting commodity prices (Dimitri et al., 2005).

However, the historical analyses are valuable because they focus on the effects policy has on risks; on the responses of farmers, input providers, and lenders to programs that reduce or manage farm-level risks; and on the consequent effects on farm structure. Modern commodity programs still clearly target the financial risks of farming (Westcott and Price, 2001). With lower risks, farmers may specialize more and may make more commodity-specific equipment investments, which may in turn lead to farm expansion. DPs may also give assurance of lower risks to lenders, who may be more willing to lend to producers who already have a guaranteed revenue source through commodity payments. Changes in perceived risks may influence farm structure, by influencing the adoption of technology as well as farmers' production, investment, and work decisions.

Recently, Key and Roberts (2007a; see also Key and Roberts, 2007b, and Roberts and Key, 2008), hereafter KR, developed an empirical analysis of modern links between farm program payments and consolidation. They used Census of Agriculture data to calculate midpoint acreages for cropland at a highly granular level—postal zip codes—for 1987, 1992, 1997, and 2002.[27] They also used census data to calculate total Government payments per cropland acre, from commodity and conservation programs, for each zip code. Payments per acre vary widely across zip codes, depending on the composition of crops grown in the area as well as historic yields from those crops.

KR found that cropland consolidated more rapidly in those zip codes with higher levels of Government payments per acre at the beginning of the period. For example, during 1987-2002, the midpoint acreage farm size increased by 46.3 percent in zip codes with the highest levels of payments, compared to 23.6 percent in zip codes with the lowest levels of payments and 11.2 percent in zip codes with no payments.[28] The association between payments per acre and the growth in midpoint acreages was statistically significant and large. It was also robust: growth rates increased

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[26]See Gardner (2002), pp. 254-271 for a discussion.

[27]Half of cropland in the zip code is on farms that are at least as large as the midpoint, and half is on farms that are no larger.

[28]These growth rates are measured as the natural logarithm of the ratio of beginning and end of period value, whereas the growth rates in figure 4 and the associated text are expressed as a percentage of the beginning value. The specific comparisons are for zip codes sorted into six classes, based on payments per acre.

consistently from one payment class to the next, and the relationship held in each time period (1987-1992, 1992-1997, and 1997-2002, as well as 1987-2002).

As part of the same research project, KR (2007b), analyzed the linkage between payments and farm business survival. They focused on wheat, corn, soybean, and cash grain (diversified) crop farms and found that farms with higher 1987 levels of Government payments per acre were more likely to still be in business in subsequent censuses. Surviving farms were also likely to grow faster the higher the 1987 levels of per-acre Government payments they received. Each effect was stronger for farms that started out larger, with size and growth measured in acres of farmland.[29]

KR identified a robust association between Government payments and later consolidation, but did higher Government payments cause faster consolidation? Three factors weigh against a causal interpretation:

Conflicting evidence at the commodity level. Midpoint acreage for fruit, vegetable, and livestock commodities that are not covered by commodity programs increased during 1987-2007 at rates comparable to those for field crops (tables 2-4). That pattern suggests that factors other than payments must play an important role.

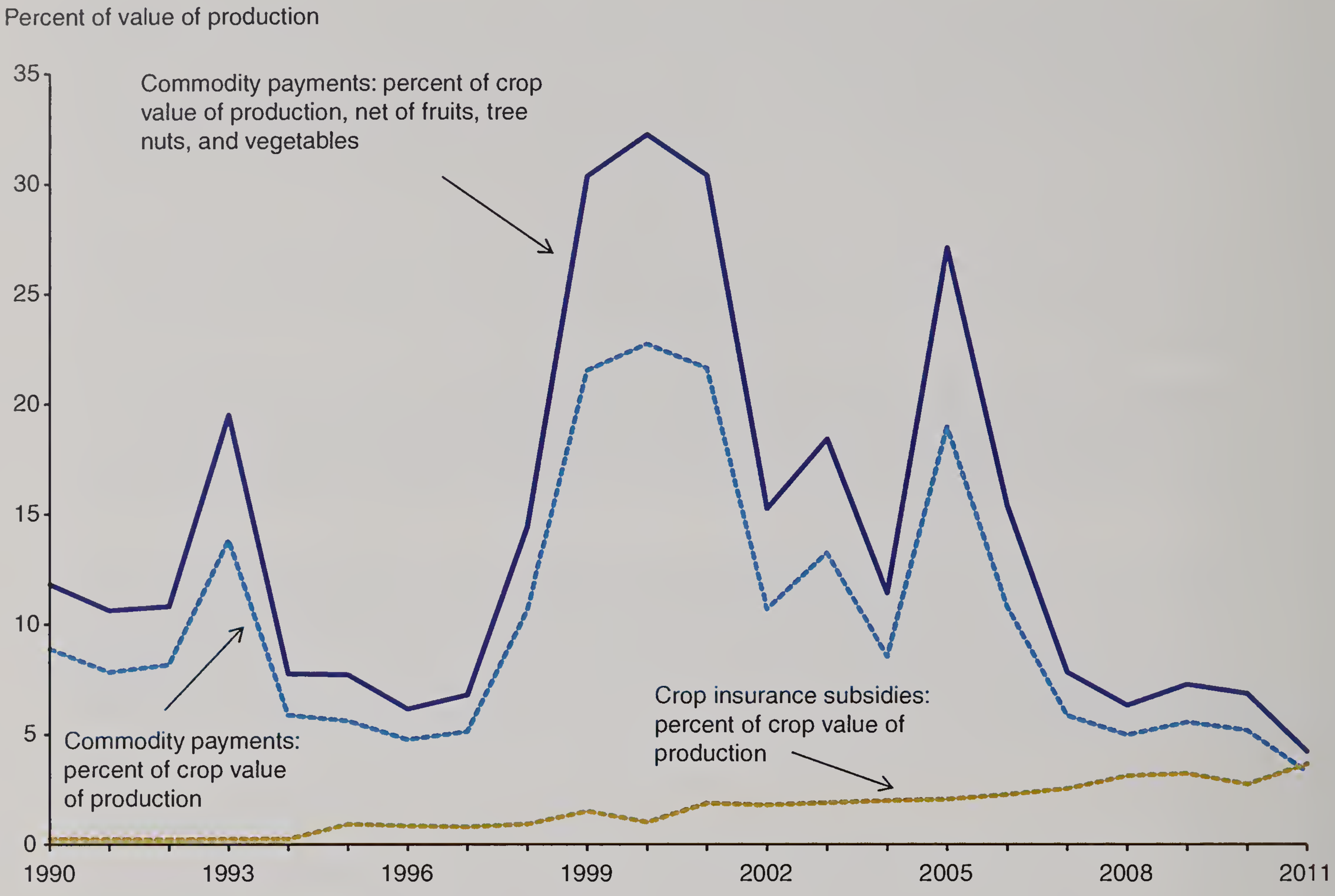
Marginal association between payments and consolidation. Much of the cropland in zip codes with low levels of payments per acre is idle, devoted to pasture and grazing, or in land retirement programs. These zip codes show very little consolidation. However, in the zip codes where most planted cropland is (and most consolidation), once payments per acre reach a minimal level, differences in payment rates have a much weaker association with consolidation.

Omission of alternative drivers. The highest rates of consolidation occurred in the Plains, Corn Belt, and Delta. They have the highest values of Government payments per acre because they have heavy concentrations of program crops and high yields on crops. They also have large, flat, and contiguous fields--land best suited for the labor-saving innovations described earlier. Although KR included several control measures (sales per cropland acre, the fraction of land devoted to cropland, beginning-of-period median size, and locational controls), there is still reason to believe that the association between payments and growth may reflect the greater adoption and use of labor-saving innovations in those regions.

KR focused on the association between Government payments and later cropland consolidation between 1987 and 2002. Significant changes in policy and in commodity markets have occurred since then. In particular, as a result of higher commodity prices and Federal spending limits on commodity programs, commodity programs payments now account for a much smaller share of the value of crop production (fig. 8). Between 1999 and 2001, Federal commodity program payments amounted to over 20 percent of the value of U.S. crop production. If the value of fruit and vegetable production is subtracted from crop production (since those commodities do not receive support), then commodity payments came to over 30 percent of the value of production. After 2005, commodity payments fell sharply, as a share of production, and by 2011, they amounted to just over 3 percent of the value of crop production (or 4 percent of crop production, excluding fruits and vegetables). Over the same period, crop insurance subsidies rose sharply and by 2011 exceeded commodity program payments.

[29]The analysis controlled for initial farm size as well as attributes of the farm's organization. It also used county fixed effects, so that higher levels of payments per acre, relative to the county's average, resulted in higher growth and survival rates, again relative to a mean for the county.

Figure 8
Commodity program payments and crop insurance subsidies, relative to the value of crop production



Sources: USDA Economic Research Service for direct payments and value of crop production; Glauber (2013) for Federal crop insurance subsidies.

Crop Insurance

The Federal crop insurance program has become a major component of agriculture support via premium subsidies and support for administrative costs provided by the Federal Government. Federal subsidies for premiums totaled $7.15 billion in 2012, and Federal support for insurance company expenses were $1.38 billion, by which time the program covered 282 million acres (Shields, 2012).

Federal crop insurance was created in 1938 but was limited in scope until Congress expanded the program in 1980 to cover many more crops and regions; in 1994 and 2000, Congress expanded premium support through subsidies and a wider range of commodity coverage. By 2012, over 80 percent of planted acreage of corn, cotton, soybeans, and wheat were covered by crop insurance (Shields, 2012; Glauber, 2013).

The Federal Crop Insurance Reform Act of 1994 (FCIRA) led crop insurance coverage to increase in the mid-1990s, from about 100 million acres of cropland in 1994 to 220 million the next year. Enrollment fell to 180 million acres in 1997 and 1998 as some initial mandatory enrollment provisions of the 1994 legislation were dropped, but the legislation nonetheless had a major impact on enrollment, which expanded steadily from 1998 to 2008.

The FCIRA provided a natural experiment for analysts interested in farmer responses to risk: expanded premium subsidies led to suddenly reduced production risks for farmers, which varied for different crops and different locations. In two papers, O'Donoghue, Key, and Roberts evaluated how the change affected farmer behavior (O'Donoghue et al., 2009; Key et al. 2006). Farmers can manage the income risks associated with farming by diversifying their sources of income. Working off the farm leaves a farmer's household income less exposed to fluctuations in farm performance. Likewise, producing a range of commodities leaves household income less exposed to fluctuations in the performance of a single crop. Each strategy carries costs of its own. Expanded crop insurance, by reducing the financial risks of farming, may lead farmers to reduce their other risk management activities.

In O'Donoghue et al. (2009), farms with expanded insurance coverage reduced their levels of commodity diversification slightly—that is, they specialized more—as greater insurance subsidies became available. In Key et al. (2006), large farms reduced their hours of off-farm work after the 1994 legislation, while small farms increased off-farm work. Because off-farm work is a substitute for onfarm work, one can infer that larger farm operators increased their hours devoted to farm work, while smaller operators reduced their farm hours.[30] With more hours to apply to farming, a farmer will likely expand the farm. The net effect would have been an increase in farm consolidation. While the effect on commodity diversification was small, the effect on labor was more substantial—up to 22 days per year for larger farms. These studies likely captured a short-run response, since they covered changes between 1992 and 1997, with the new legislation being passed in 1994. Major changes in farm size—which requires assembling land, capital equipment, and labor—may take longer.

A third study (Claassen et al., 2011) modeled the combined impact of Federal disaster programs, crop insurance, and commodity program support on land use changes, through farmer decisions to convert grasslands to cultivated croplands in North and South Dakota. They found that the programs raised the returns to cultivation, thereby increasing cultivated cropland by 2.9 percent between 1998 and 2007. The largest effect was from disaster assistance (1.2 percent) followed by crop insurance (1.0 percent) and marketing loan benefits from commodity programs (0.7 percent). By shifting more land from grassland to cropland, the programs would also increase midpoint cropland acreage by a similar modest amount.

Agricultural production is subject to substantial production and price risks. To manage the risks associated with greater specialization and substantial investments in capital equipment, many farmers look to institutions for support. Some strategies to manage farm risks, like contracting, have been developed in the private sector. Government commodity and crop insurance programs give additional tools for managing farm financial risks. To the extent that the programs reduce risks facing farmers, they may encourage farmers to invest more in labor-saving innovations and to specialize more in agriculture and in specific commodities, which in turn could affect farm structure and help shift production and acreage to larger farms.

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[30]The analysis relied on Census of Agriculture data, which records days worked off the farm, but does not record onfarm labor hours. Hence, the analysis focused on off-farm employment.

The Future: Will Family Farms Still Dominate Crop Production?

The largest U.S. farms are now very large indeed. For example, a large cattle feedlot firm operates 10 feedlots, with a combined capacity of 520,000 head; an Oregon dairy farm has a milking herd of 16,000 head, and also farms over 30,000 acres of cropland for forage, wheat, and vegetables; a Florida firm farms over 180,000 acres of sugar cane; and a California firm farms 150,000 acres, primarily in cotton and tomatoes, in that State and another 30,000 acres in Australia.[31] Each has hundreds of employees and teams of professional managers; none are owned and operated by a single family.

These are exceptional operations, easily identified through Internet searches. But there are also many less well-known but very large farming operations: 1,140 U.S. farms had at least 10,000 acres of cropland in 2011, up from 409 in 2001 (each estimate is based on ARMS data). Do the largest farms simply represent the size of a farm that a family can now manage, and that many more families will manage in the future, or do they signal a more fundamental shift toward more corporate, complex, and bureaucratically organized farm firms?

This is not a new question. Fitzgerald (2003) summarizes the enthusiasm for large, bureaucratically organized farming corporations expressed by some economists, engineers, businessmen, and political leaders during the 1920s. Those firms often operated multiple farms with hired farm operators and skilled professionals on staff; invested significant amounts in machinery, structures, and transportation links; and developed detailed operating protocols and production plans to be applied across their farms.

They were organized much like the "bonanza" wheat farms in the Red River Valley in Minnesota and North Dakota in the late 19th century (Allen and Lueck, 2002). Bonanza farms were integrated into all stages of production, from sod-busting to processing, and were highly mechanized, with the latest large-scale farm machinery. Owned by absentee investors, most were managed in multiple units, with divisions of approximately 5,000 acres as well as subdivisions of 1,200 to 1,800 acres. Managers received salaries and profit-sharing commissions, manual laborers were paid a daily wage and worked under rigid rules, and technical specialists at the firms' headquarters received salaries.

Between 1875 and 1890, bonanza farms were generally profitable and were hailed as the future of agriculture. Eventually, however, the farms became unprofitable, and most had disappeared by the 1920s. Similarly, few of the farms touted by the subjects of Fitzgerald's book survived the Great Depression. Family farms accounted for most agricultural production in the period, and they continue to do so in the United States today despite the major changes in farm structure and despite the differing organizational structures used by the very largest farm firms.

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[31]The cattle feeder is Cactus Feeders (www.cactusfeeders.com); the dairy operation is Three Mile Canyon Farms (www.threemilecanyonfarms.com); and the sugar business is U.S. Sugar (www.ussugar.com); data on each are drawn from their websites, and not from USDA data. The California firm is the JG Boswell Company, and the information is taken from the 2009 *Western Farm Press* obituary for founder JG Boswell.

Family Farms in Today's Crop Agriculture

ERS defines a family farm to be one in which the principal operator, and people related to the principal operator by blood or marriage, own more than half of the farm business.[32] Family farms are defined by ERS only by ownership and operation, and not by size or by labor commitments. Large family farms rely heavily on hired labor, rented land, and contracted services to operate their businesses. However, the definition makes an important point: businesses owned and operated by family groups—a specific and distinctive type of organization—continue to dominate agricultural production in the United States, even as production has shifted to much larger family businesses.

Today, 96 percent of U.S. farms with crop production are family farms, and they originate 87 percent of the value of crop production (table 17). Non-family farms account for less than 6 percent of corn and soybean production; they are far more important to fruit, vegetable, and nursery production, where the 3-7 percent of farms that are non-family operations account for 30-35 percent of the value of production (implying that some are very large farms). But even there, family farms handle 65-70 percent of the value of production.

Table 17
Family farms in crop production, 2011

Commodity	Family farm share	
	U.S. farms	Value of production
	Percent	
All crop production	96.4	86.6
Corn	97.2	94.2
Cotton	96.0	91.5
Peanuts	93.8	84.0
Rice	89.4	88.2
Soybeans	97.2	94.8
Wheat	96.7	93.5
Vegetables/melons	96.0	69.3
Fruits/nuts	92.8	65.7
Nursery	97.0	70.3

Note: Family farms are defined as those in which the principal operator, and people related to the principal operator by blood or marriage, own more than 50 percent of the farm business.
Source: 2011 Agricultural Resource Management Survey, Phase III, all versions.

[32] A farm operator makes day-to-day management decisions for the farm business. A farm may have multiple operators. ARMS questionnaires ask for a principal operator, and ask whether that operator and persons related by blood or marriage own more than 50 percent of the farm business, where the business consists of assets owned by the farm—including land; equipment and structures; inventories of livestock, production inputs, and harvested crops; and liquid assets such as cash.

Family farms can be sole proprietorships, but they are also often organized as partnerships or corporations (table 18). Non-family farms include those operated by cooperatives, by hired managers on behalf of non-operator owners, by large corporations with diverse ownership, and by small groups of unrelated people (often in partnerships or corporations).

There is no evidence of any systematic decline in family operations: the shares of farms and value of crop production held by family farms show no trends since the initial ARMS in 1996. Although none of the four large farm firms noted at the beginning of this section above could be classified as a family farm, 86 percent of farms with at least 10,000 acres of cropland are family operations.

While there are large and complex nonfamily operations in U.S. crop agriculture, and some have been organized recently, there are also examples of large nonfamily corporations that have left farm production in recent years and moved to a coordinating role. For example, Dole Foods once operated extensive farming operations in California and Arizona. Today, it leases 14,000 acres in those States from landowners who purchased the land from Dole. Most of that land is now farmed by independent growers, most of which are family operations, under contract arrangements with Dole. Fresh Del Monte, a major competitor of Dole in fresh fruits and vegetables, has taken a similar approach on U.S. land that it once farmed and now sources primarily from contract growers.[33] These more complex arrangements are shifting agricultural production to family operations, while leaving large distributors as coordinators of production and providers of inputs.

The success of family farms in agriculture arises from several factors. First, although technological scale economies exist in many farm production processes, they are rarely large enough or extensive enough to be beyond the scope of a family business (Deininger and Byerlee, 2012). Even in industrialized livestock sectors, where large corporations coordinate most hog and broiler production through their role as integrators, most production is still carried out on family operations under contract with the integrators. Measured scale economies in farm production, while important, appear to be exhausted or largely realized at still-modest sizes.[34]

Table 18
Family and nonfamily crop farms, by legal status, 2011

	Family farms		Nonfamily farms	
Legal status	Farms	Production	Farms	Production
	Percent of all family or nonfamily farms			
Sole proprietorship	92.1	66.5	46.5	11.1
Partnership	3.8	16.7	24.8	31.3
Corporation	3.1	15.4	17.7	49.6
Other	1.0	1.4	11.0	8.0
	100.0	100.0	100.0	100.0

Note: Production refers to the value of crop production. The legal status "other" includes estates, trusts, cooperatives, grazing associations, and public agencies.
Source: 2011 Agricultural Resource Management Survey, Phase III, all versions.

[33]See the 2006-2011 annual reports for each company, in sections referring to "business" and "properties."

[34]See MacDonald and McBride (2009), Key and McBride (2007) for hogs, MacDonald and Wang (2011) for broilers, and Mosheim and Lovell (2009) for dairy.

Second, analysts widely believe that managerial diseconomies of scale set in as farms get large enough to have to rely extensively on hired managers and workers: the firm's owners must then closely monitor the decisions made by hired staff (Allen and Lueck, 2002; Deininger and Byerlee, 2012; Gardner, 2002). These diseconomies are thought to be particularly acute in agriculture, because of the degree of local knowledge of soils, nutrients, pests, and weather patterns required to effectively manage cropping and animal husbandry decisions, and because sudden changes in weather or in animal performance demand quick and informed reactions.

Challenges for Family Farms

Despite the historical predominance of family farms as an organizational mode, several factors could undermine this tendency. First, even though families can manage much larger operations than in the past, the land and capital equipment requirements for these businesses may create unacceptable financial risks for many families. With Corn Belt cropland selling for $7,000 an acre in 2012, a farmer aiming to produce 600 acres of corn and 500 of soybeans, close to the midpoint acreages of table 2, would need to assemble over $8 million of land, equipment, and structures. Irrigated California cropland was valued at $12,000 per acre in 2012; a farmer with 300 acres of irrigated fruits and vegetables would need to assemble over $4 million in land, equipment, and structures.[35] Much of this capital may be leased or rented, but the equity and debt required for the owned assets may be daunting; even if feasible, most or all of a family's wealth could be tied up in one risky enterprise.

The risks have become more salient in recent years, with sharp fluctuations in global commodity prices for crops and for energy inputs (Baffes, 2013). While public policies give some insulation in the form of commodity and crop insurance programs, and private institutions in the form of contracting for inputs and products, these movements represent unprecedented volatility for many producers. As a result, operators of large family farms may show more interest in different ways of organizing farm production and accessing capital. They are likely to explore more complicated ownership and management structures for large family farms, with non-operator equity and resource providers, the sharing of assets and services among farms, and more complex contractual relationships with input suppliers and with processors.

A second deterrent to would-be family farms may be created by new precision technologies that erode the managerial diseconomies associated with using hired managers and labor, in turn reducing the advantages of close-knit family operations. In livestock production, specialized confined feeding operations rely on housing with automated climate controls and sanitation equipment, strict biosecurity procedures, specifically formulated purchased feeds, and tightly controlled animal genetics. Those features may have reduced the value of localized farm and herd-specific knowledge and improved the capability for monitoring the performance of hired managers, allowing for greater reliance on hired managers, workers, and nonfamily organization (Allen and Lueck, 2002: Deininger and Byerlee, 2012).

Some see such developments emerging in crop agriculture (Deininger and Byerlee, 2012; Byerlee et al., 2012; Boehlje and Gray, 2009). Large firms now routinely manage businesses with well over 100,000 acres in South America, Ukraine, and Russia. These firms tend to use genetically engi-

[35]Cropland values are from *Land Values: 2012 Summary* (USDA National Agricultural Statistics Service), while the equipment and structures estimates are averages for like farms drawn from the 2011 ARMS, Phase III.

neered seeds and no-till cultivation techniques to limit the amount of management time expended on field-level weed, pest, and nutrient management decisions. They also use the communications, measurement, and monitoring capabilities now incorporated in precision agriculture technologies to provide the detailed and localized field and farm level information that was previously available only through persistent personal experience in fields. They have introduced routines, process controls, and standardized operating procedures into field-level farm management, and they employ highly trained scientific and business staff to handle technical tasks. Their size and geographically dispersed operations provide them with opportunities to reduce costs through more intensive use of capital equipment, and they have been able to tap independent investors for financing.

Such organizations remain rare in the United States, where family farms still dominate U.S. crop agriculture even as it has shifted to much larger farms. They will continue to do so as long as they are able to limit and manage the financial risks associated with managing large and capital-intensive businesses, and as long as the strengths of family organizations—localized knowledge, quick and flexible adjustments to changed circumstances, and the incentives to act on each of those—remain necessary to crop production.

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Glossary

Acre: An area equal to 43,560 square feet or 4,840 square yards.

Cropland: Land that is suitable for or used for crops. In USDA data, cropland includes cropland harvested, cropland used only for pasture or grazing, cropland on which all crops failed or were abandoned, cropland in cultivated summer fallow, and cropland idled or used for cover crops or used for soil improvement but not pastured or grazed.

Family farm: In ERS analyses, any farm for which the principal operator, and persons related to the principal operator by blood or marriage, own more than 50 percent of the farm business.

Farm: In USDA data, any place from which at least $1,000 worth of agricultural commodities were produced or sold, or normally have been sold, in a year.

Farm operator: A person who operates a farm, either doing the work or making day-to-day operating decisions for the farm.

Genetically engineered (GE) crop varieties: GE techniques allow a more precise alteration of a plant's genetic makeup than is possible under conventional plant breeding, and permit targeting single genes in a plant's DNA. Genetic engineering has led to the introduction of traits for herbicide tolerance (HT) in alfalfa, corn, cotton, sugar beets, and soybeans, and for resistance to certain insect pests (Bt) in corn, cotton, and papaya.

Harvested cropland: In USDA data, cropland from which crops were harvested and hay was cut, land used to grow short-rotation woody crops, orchards, citrus groves, Christmas trees, vineyards, nurseries, and greenhouses.

Labor-saving innovation: An innovation that reduces the amount of labor needed for any given amount of output. Innovations may be mechanical, material, biological or organizational. Strictly speaking, it is distinct from input substitution, in which other inputs are substituted for an input whose price rises, in an amount sufficient to maintain output.

Mean: For a dataset, the mean is the sum of the values divided by the number of values. The mean size of a farm, measured by cropland, is the sum of all cropland acres divided by the number of farms with cropland.

Median: The numerical value separating the top half of a distribution from the bottom half—the 50th percentile of values. For cropland, the median farm size is that value which splits the distribution of farms: half of all farms have at least that value of acres, and half have no more.

Midpoint: In this report, the midpoint acreage for cropland is that value for which half of all cropland is on farms that are at least that large, and half of all cropland is on farms that are no larger than that size. Technically, it is the median of the distribution of cropland by farm size.

Precision agriculture: A set of management practices and information technologies (IT), often incorporated in farm equipment, that measure and help to manage intra-field variations in soil attributes, pest presence, product attributes, and production outcomes.

Principal farm operator: The person primarily responsible for day-to-day management decisions on the farm.